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CONCEPTIONS ABOUT ELECTRICAL CIRCUITS OF ENGLISH AND FRENCH PUPILS FROM NOVA SCOTIA IN CANADA

English And French Conceptions On Electric Circuits

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KEY WORDS

*Conceptions
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ABSTRACT

This research study was designed to identify the conceptual understandings of 89 students from the region of Clare in French-language public schools and 105 students from the Argyle region in French immersion public schools in Canada on the operation of simple electrical circuits. To this end, they completed a pencil-and-paper questionnaire of sixty minutes in duration. The analyses of the data show clearly the preponderance of erroneous understandings by students related to the concepts of current and voltage among other related concepts identified in the international review of the literature. Thus, despite the cultural and language differences, their conceptual understandings related to the simple electrical circuit are similar. A conclusion and didactical impact are included.

1. Introduction

Extensive research conducted with elementary and secondary pupils (7 to 14 years old) about their conceptions related to different natural and constructed phenomena with which they interact daily reveals that they are similar despite socioeconomic and cultural differences (Métoui & Baulu MacWillie, 2013, 2015; Tao et al., 2012; Allen, 2010; Jabot & Henry, 2007; McDermott, 2004). On this subject, McDermott (2004) highlighted that “[...] research findings on students’ understanding of physics indicate that some misconceptions about the physical world are familiar to students of different nationalities, from different socio-cultural backgrounds and different levels of education and varied ages”. (Page 1) Similarly, Tao et al. (2012) demonstrate that Chinese and Australian children from high and low socioeconomic status have the same spontaneous conceptions: “The findings revealed that participating six children from schools with high socioeconomic status from China and Australia demonstrated similar profiles in their understanding of science.” It is important to note that these profiles are not the same in the case of secondary pupils and depends on many factors. For example, the Canadian results of the OECD PISA study (2015) demonstrate that French-speaking students (15 years old) in a minority secondary school system perform less well than English-speaking students in a majority school system in sciences. In the case of elementary school students, we found no indication of their science performance. In the present exploratory qualitative research, we will first summarise a review of this work relative to the phenomena requiring the understanding of scientific concepts as electrical current, time, speed, acceleration, force, energy, heat, and temperature with elementary pupils aged 7 to 12. Then, we will present the results of our research on a comparative study of French and English-speaking students from Nova Scotia in Canada to verify if the Anglophone performs more than French as in the secondary school revealed in the OECD PISA study. In this, we have identified the conceptions of Anglophone and Francophone students in Nova Scotia on the

principles of simple electrical circuits inscribed in the Elementary School Science of the Ministry of Education.

2. Literature reviews about pupils’ conceptions from different cultures and countries

Studies carried out in many countries with pupils aged between 8 and 12 demonstrate that they have relatively the same conceptions to explain different physical, chemical and biological phenomena with which they interact daily. Below we summarize the most widespread pupils’ conceptions from different countries about notions related to the physical world. These studies attest to the universality of their understandings.

2.1. Conceptions about velocity

Works done with pupils aged 7 to 12 and attending primary schools in Italy (Invernizzi et al., 1989), in France (Canal, 1986), in Canada (Métoui & Baulu MacWillie, 2013) and elsewhere indicate that their spontaneous conceptions concerning speed and time, despite the cultural and economic differences of these countries. The majority of pupils associate time with either: 1. The units of measurement (e.g., hours, minutes, seconds); 2. The duration of the day, month, year or century; 3. The climate (e.g., autumn, winter, spring, summer); 4. The games and accidents (e.g., car race); 5. To life (e.g., joy, sadness, luck) and 6. To speed of movement or speed. As for speed, they associate it with movement without acceleration or with the characteristics of moving objects (e.g., the engine and the mass of a car).

2.2. Conceptions about force, motion, acceleration and gravitation concepts

Much research has focused on the conceptions of students between 10 and 14 years old on the concepts of force, motion, and gravitation (Watts, 1983; Métoui & Trudel, 2017). The misconceptions commonly accepted by students from different cultures and countries are: the motion implies force; when two objects have the same position, they should have the same

velocity; the velocity of an object is proportional to the force applied; if an object moves in the circular path, a circular force tends to move this object in its path; acceleration is an increase in speed; speed of a falling body is proportional to its weight; weight is the quantity of matter (mass), energy is a force and there is no gravity on the moon.

2.3. Conceptions about electrical circuits

In the case of electrical circuits, regardless of the country, the pupils aged between 8 and 12 have the same erroneous conceptions. Indeed, studies conducted in the USA (Fredette & Lochhead, 1980), Canada (Métoui et al., 2016; Métoui & Baulu MacWillie, 2015); France (Tiberghien & Delacote, 1976; Thiberghien, 1983), New Zealand (Osborne, 1982); Australia (Webb, 1992) and elsewhere with pupils in elementary schools established that their majority refer to one of the erroneous following models to explain the flow of the current in a simple circuit consisting of a battery, light bulb, and electrical connection wires: (1) Unipolar model; (2) Clashing currents model and (3) Attenuation model. Relative to the transformation of energy in a simple circuit composed with bulb, battery and two wires their conceptions are as; 1. There is no difference between light and electricity since light produced by electricity; 2. There is a difference between heat and electricity since with heat one cannot operate devices such as a television; 3. The light in the bulb comes from electricity contained in the battery, and 4. There is a difference between light and electricity since light cannot produce electricity.

2.4. Conceptions about heat

Students' conceptions of heat and temperature have been the subject of much work around the world (Erickson, 1980, Engel Clough & Driver, 1985; Tiberghien, 1985; Carlton, 2000; Sözbilir, 2003; Chu et al., 2012; Métoui, 2019). Students consider heat as a substance with properties attributed to material objects and often see hot and cold as two distinct and opposite phenomena that are not part of the same continuum. Also, for most, the temperature is a property of matter, some objects being hotter or

colder than others (for example, metal are more cooling than wood). Finally, relative to the relationship between heat and temperature, for many students, the temperature is a measure of the degree of coldness or warmth of a substance. Note that many well-known scientists constructed some of these erroneous conceptions during the eighteenth century (Fox, 1971; Métoui, 2019).

2.5. Conceptions about light and vision

The notions of light and vision in students have also been the subject of many works (Tiberghien et al., 1980, Selley, 1996, Dédès & Ravanis, 2007; Ravanis et al., 2010; Métoui, 2012). The following conceptions identified in these works are related to the students' daily experience and their first intuition: 1. The size of an object's shadows varies with the intensity of the bulb; 2. Light propagates in a straight line, but only in the horizontal direction; 3. Light is reflecting when meeting an obstacle on its path; and 4. Light changes direction in the same area of propagation.

3. Methodology and population

To identify the conceptions of 89 pupils from the region of Clare in French-language public schools and 105 from the Argyle region in English-language public schools aged between 10 and 12 years, we have given them, a paper and pencil questionnaire of sixty minutes' duration. To complete it, they had to use their conceptions since they have received little training on the topic connected to the concepts related to the study of simple electrical circuits. In table 1, we present information relative to the two groups of students belonging to two different communities in Nova Scotia (Canada). These studies attest to the universality of their understandings.

Table 1.
Population

Region of Clare, Nova scotia	Region of Argyle, Nova scotia
Linguistic	
Spoken languages: French vernacular with significant linguistic variations and English	
Economic	
Diversified economy helped by the Economic Development Council of Nova Scotia (CDENE).	Economy a little more prosperous because of the lobster fishery that brings in a lot of money. Support from the Nova Scotia Economic Development Council (CDENE).
School	
Public elementary and secondary schools.	
Geographical	
The fishing industry is important in the regions of Argyle, Clare, Isle Madame and Cheticamp. The most prosperous in Atlantic Canada is the Argyle region.	

4. Paper-pencil questionnaire: Construction and analysis

The questionnaire we constructed covers some program concepts related to the study of the simple electrical circuit, especially the law relatively the flow of the current. For that, we presented them with three questions. Below we present the objective of each question and its analyses.

5. Objective and analyses of the data of the first question

This question served to know how the students explain to light the bulb we must connect the (+) and (-) terminals of the battery to its poles. The analyses of the answer can be classified into three categories conceptual representations described below.

5.1. Category 1: Unipolar model

Following the analysis of pupils' responses, we identified two subcategories related to the unipolar model.

5.1.1. Subcategory 1.1

The current flows from the pole (+) towards the light bulb. It is causal reasoning according to which a current flow from one of the two battery terminals and goes up to the lamp to illuminate its. It should be noted that very few pupils refer to this erroneous model. Tiberghien (1983) underlined that most of the pupils abandon this model during the training of the electric circuits. Table 2 illustrates some pupils' explanations.

Table 2.
Pupils' answers: Subcategory 1.1

French pupils: 2/89	English pupils: 5/105
"We watch it on the canal 'Discoveries'." (F ₂₈)	"The positive end has the most energy." (E ₈₂)
"Because the plus is stronger." (F ₆)	"The reason why the light will heat up is because of the + sign." (E ₈₄)

5.1.2. Subcategory 1.2

The current moves from the pole (+) to the pole (-) and then stop. Contrary to the precedent unipolar model, the current flow from one pole to the other pole of the battery for the light bulb to come on. These students probably think so to take into account the necessity to use the second wire. Table 3 illustrates some pupils' explanations.

Table 3.
Pupils' answers: Subcategory 1.2

French pupils: 6/89	English pupils: 2/105
"I chose (c) because that's what I think it is." (E ₂₉ /10 years old)	"The reason that I picked (c) is that that is the only one that is right for me." (E ₉₄)
"I think (c) is good because they both work together." (E ₈₂)	

5.2. Category 2: Clashing currents model

Two currents move from (+) and from (-). It should be noted that the anglophone students referred to the word energy without, however, explaining its production in the battery. Table 4 illustrates some pupils' explanations.

Table 4.
Pupils' answers: Category 2

French pupils: 28/89	English pupils: 32/105
“Because the two wires are touching each other and when they meet at the bulb, the light bulb comes on.” (F ₇₂)	“Because it can give the bulb a source of D.C. energy.” (E ₃₃)
“Because it lights up when it is at (+), then it does not light when it is at (-).” (F ₈₃)	“When you put the positive to negative it creates energy made from the acid in the battery.” (E ₃₈)

5.3. Category 3: Circulatory model

The current moves from the pole (+) to the pole (-) and continues to circulate. Table 5 illustrates some pupils' explanations.

Table 5.
Pupils' answers: Category 3

French pupils: 48/89	English pupils: 57/105
“I think it's going in a circle because if it stops, the light will have no electricity.” (E ₆₇)	“Because that is how I thought it would light up before I read it.” (E ₈₅)
“Because it needs to continue because if it does not continue, the light will stop.” (E ₇₀)	“I think it will light up because the energy continues to circulate through the battery and causes the energy to go to the light.” (E ₉₁)
“The reason the light bulb comes on is through both wires and the battery.” (E ₈₅)	“Because it continues to circulate.” (E ₉₅)

Conclusively, only five French pupils and nine English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

6. Objective and analyses of the data of the second question

The relative data to this question relates to the principle conservation of the total charge revealed two categories of answers as illustrated below. According to this principle, in each moment the intensity of the current is the same at all points of the wires. The analyses of the answer can be classified into two categories described below.

6.1. Category 1: Attenuated current model

Following the analysis of pupils' responses, we identified two subcategories related to the attenuated current model.

6.1.1. Subcategory 1

The current in the B wire is weaker than the current in the A wire. Table 6 illustrates some pupils' responses.

Table 6.
Pupils' answers: Subcategory 1

French pupils: 19/89	English pupils: 32/105
“The B wire will make the light more than wire A.” (E ₂₈)	“The B wire is weaker because electricity goes up and the A wire happens to be at the top.” (E ₂₅)
“Because (-) it means less, less power, (+) it means there is more power, (+) for (+).” (E ₆₈)	“The current in the B wire is weaker because it is on the negative (-) and the current A wire is stronger because it is on the positive (+).” (E ₄₁)
“The light bulb will turn on because on the battery, the side where there is the B there is a minus (-), and where there is the A, there is a plus (+).” (E ₇₁)	“The current in the B wire is weaker because B wire is shorted than A wire.” (E ₃₆)
“The bulb will light up because the A wire is stronger.” (E ₇₂)	“The current B wire is weaker because it is on the (-) side.” (E ₃₉)

6.1.2 Subcategory 2

The current in the B wire is stronger than the current in the A wire. Table 7 illustrates some pupils' responses.

Table 7.
Pupils' answers: Subcategory 2

French pupils: 6/89	English pupils: 6/105
"I think B is stronger because the B cable is black and bigger." (E ₁₈)	"Because B is touching the bottom and that is where the bulb works." (E ₃)
"I think it's B because I tried it before." (E ₂₉)	"The bulb lights up with the A wire and the B gives it strength." (E ₈₇)
"It's because it's a current that goes on all the time." (E ₄₂)	"Because the B wire has to be stronger than the A wire." (E ₈₉)

6.2. Category 2: Scientific model

The current in the B wire is the same as the one in the A wire according to the principle of the conservation of the electric current Table 8 illustrates some pupils' responses.

Finally, only 6% (5/89) of French pupils and 10% (11/105) of English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

Table 8.
Pupils' answers: Category 2

French pupils: 59/89	English pupils: 56/105
"The electricity flows in the metal faster and it makes a current." (F ₂)	"With the choice, I have made the bulb will light up because the B wire is the same as the A wire." (E ₂₇)
"From the photo, the wires are equal." (F ₈)	"It will light up because the bulb has a source of DC energy." (E ₃₃)
"If they were not the same, it would not work." (F ₂₂)	"It takes twice ends of a battery and a wire to light up the bulb." (E _{50/11} years old)
"The c because that's what I think." (F ₃₃)	"Because the wires look the same. They just connected to different ends." (E ₇₉)
"Because it's electric current and the light will come on because it's the same battery." (F ₅₂)	"The current B and A has to be the same or the light won't work. If the B side was stronger than the A-side it wouldn't work, the same if it was switched." (E ₁₀₅)
"Because if both are the same, they would light up easier together because there is the same energy." (F ₇₅)	

7. Objective and analyses of the data of the third question

The objective of the present question is to verify if the students are aware that if we touch the (+) and the (-) poles simultaneously we "close" the circuit then it would be deadly. The analyses of the answers can be classified into three categories described below.

7.1 Category 1: Bipolar model

It would be deadly to touch both terminals at the same time. Table 9 illustrates some pupils' responses.

Table 9.
Pupils' answers: Category 1

French pupils: 6/89	English pupils: 4/105
"If you touch both sides, you could die because it's so strong." (F ₂₇)	"Neither, you would have to touch both poles to make a complete circuit to be shocked." (E ₄₃)
"We'll be dead when we touch both sides." (F ₂₈)	"Both ends would be deadly to touch because it is way stronger than a regular light bulb. A regular one would shock you but this one would really hurt you." (E ₁₀₅)
"Both sides because both are very hot." (F ₃₁)	

These pupils have not justified their answers by indicating that our body is a conductor of electric current like the wires, and we closed the circuit with our fingers on touching the two terminals. Despite this, they specified the need to use the two poles of the battery.

7.2. Category 2: Unipolar model

In this category, we have grouped the answers into three subcategories as described below.

7.2.1. Subcategory 1

It would be deadly to touch to the negative terminal. Table 10 illustrates some pupils' responses.

Table 10.

Pupils' answers: Subcategory 1

French pupils: 3/89	English pupils: 4/105
"The negative because the positive put electricity in the bulb." (F ₄)	"I think the negative side would be deadlier to touch because the negative side is stronger." (E ₄₆)
"I think the (-) is going to be deadly because it's lower." (F ₂₀)	"I think it would be the negative side because the negative side holds more power." (E ₆₇)
"The - is the answer because I have tried it before." (F ₆₇)	"I think negative would be deadly." (E ₇₂)

7.2.2. Subcategory 2

It would be deadly to touch one of the two terminals (+ or -). Table 11 illustrates some pupils' responses.

Table 11.

Pupils' answers: Subcategory 3

French pupils: 8/89	English pupils: 35/105
"I will not touch a wire because the two of them would electrocute me." (F ₃₆)	"It would be deadly to touch because it is high volts." (E ₃)
"It does not matter; it conducts the same volt." (F ₄₈)	"Yes, because the battery would be so powerful." (E ₉)
"There is no difference." (E ₅₂)	"I think it would be deadly to touch because 1000 volts is a lot! And it would shock you." (E ₇₇)
"They will have the same amount of electricity." (F ₆₂)	"Yes, it would be deadly to touch because of the electricity." (E ₈₀)

7.2.3. Subcategory 3

It would be deadly to touch the positive terminal: there is more electricity on the pole (+); there are more volts on the (+); terminal (+) is stronger than terminal (-) of the battery; the (+) had more energy, and the power comes out of the pole (+). Table 12 illustrates some pupils' responses.

Table 12.

Pupils' answers: Subcategory 1

French pupils: 26/89	English pupils: 22/105
"I think + because + has the most energy." (F ₅) "(+), because that's where all the force is gone." (F ₈) "I think (+) is deadly because with (+) there are more volts." (F ₁₁) "I think the (+) because it gives more electricity because the (+) means more volts." (F ₁₅) "It would be the (+) the deadly wire because the energy gets out." (F ₂₁) "That would be the (+) side because in there, there are very large amounts of electricity." (F ₅₈)	"The positive end has metal which is deadly to touch." (E ₁₄) "It would be deadly to touch the (+) side of the battery because that is where the power comes out." (E ₁₅) "It would be a positive charge because it has more volts on that side." (E ₄₁) "The positive side would be deadlier to touch because it has more voltage in it." (E ₄₂) "I think is the positive side would be deadlier to touch because the positive side is stronger than the negative side." (E ₄₅)

7.3. Category 3

For pupils in this category, there is no danger to touch the terminals. Because the battery is not connecting with a bulb or any material that conducts the electric current, thus, no flow can circulate since the battery is not inserting into a closed circuit. Table 13 illustrates some pupils' responses.

Table 13.
Pupils' answers: Category 3

French pupils: 18/89	English pupils: 27/105
"None because you need a source of ground, but if there is a source of ground, both can kill you." (F ₁₆)	"If it was working it may shock you but if it isn't working it probably wouldn't." (E ₅)
"If you had a piece of iron, yes it would be deadly." (F ₃₂)	"The battery would not be deadly because there are no wires to it." (E ₃₅)
"Because the poles, if it has to work, there must be a ground wire." (F ₅₆)	"It depends if the battery is connected to wires to be deadly. If it's connected, don't touch it." (E ₅₈)
"No, it will not be dangerous because there is no iron touching it." (F ₅₇)	"Neither pole would be deadly to touch because the electricity can't go from a battery to your body." (E ₆₀)
"No pole because there is no electricity in a battery." (F ₅₉)	"The battery would not be deadly to touch because it has no wires hooked to it." (E ₆₅)
"Not a pole would be deadly to touch, only if the battery was plugged." (F ₆₅)	"I don't think it would kill you because there is no energy going these." (E ₈₅)
"No pole would be deadly to touch unless you touch it with metal." (F ₈₁)	

After all, only nine French pupils and 13 English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

Conclusion and didactical impact

The results of this analysis attest to the striking parallelism between their conceptions and are

like those identified in a different country. Thus, there is no significant difference between the conceptions identified, while a study conducted by the OECD (2015) indicates that English-speaking high school students in Canada perform better in science than their counterparts in minority communities. In conclusion, we will present our hypotheses to try to understand why, at the primary level, there is no significant difference while at the secondary level, we have a noticeable difference.

The analysis of the conceptions of French and English-speaking pupils shows that they share the same conceptual understandings about the concepts underlying the functioning of electrical circuits. Thus, the mother tongue does not seem to influence their conceptions. How can the results of the OECD study show that, at the secondary level, Francophones do not perform as well as Anglophones? Here are some hypotheses of answers: (1) Language requirements: Absence of textbooks in French adapted to students' language skills; (2) Teacher training: Difficulties in recruiting students from minority francophone regions by faculties of science of education; (3) Policies of Departmental Leaders on the Training of Students in Minority Environments.

The results of our research show that, in the case of electrical circuits, French-speaking pupils aged between 10 and 12 years old perform as well as the Anglophone pupils. However, we should ask them about other scientific phenomena to generalize our results. In relative terms, secondary school pupils whose Anglophone students perform better than those of Francophone Minority students should identify their conceptual representations using a qualitative methodology to understand better the difference observed by the OECD PISA (2015) research.

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THE POTENTIALITY OF BLACK WOMEN NARRATIVES FOR INCLUSIVE EDUCATION

Developing Other Subjectivities At School

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ABSTRACT

*The paper aims to present the results of a research developed with narratives written by Brazilian Black Women, as well as to discuss its educational potentiality. The research data was composed of 36 autobiographic narratives published by Black women in a blog called *Blogueiras Negras*, between 2013 and 2016. The research relies on post-structuralism perspective, articulating Foucaultian Studies, the field of Multicultural Education, and the Critical Race Theory-CRT. The analysis shows that the blog works as an essential educative place, where women of color feel safe to share their experiences. The narratives about the school are mostly discriminatory and painful, which made it possible to problematize the processes of learning and teaching. The paper concludes by discussing how the autobiographic narratives of Black women in classrooms can help students and teachers to work forward an inclusive education.*

1. Brazilian Blackness And Education: An Introduction

Stories matter. Many stories matter. Stories have been used to expropriate and do evil. However, stories can also be used to empower and humanize. Stories can destroy the dignity of a people, but stories can also repair that lost dignity. (Adichie, 2009)

This paper aims to discuss the potentiality of stories about schooling, told by Black women in a blog called *Blogueiras Negras* (BN). The blog is a Black feminist community, where Brazilian Black women are invited to publish essays about their thoughts and experiences. Among hundreds of published texts, it was selected those with the narrative style. In these texts, Black women write in the first person and tell their stories of life. These stories show a powerful process of subjectivation, which the woman recognizes itself as a Black woman. Telling their experiences at the school, we can realize how violent can be an institution where learning and coexistence are the main goals. At the same time, the paper points out the importance of sharing and producing autobiographic narratives like these for developing other subjectivities at school.

The discussion presented in this paper is part of the results of an investigation developed during a Ph.D. course in education (2014-2018). The research (Weschenfelder, 2018) sought to understand how the processes of subjectivation of Black subjects are produced in contemporary Brazil and how these subjectivities help us to problematize Multicultural Education. The research relies on post-structuralism perspective, articulating Foucaultian Studies and the Education field for focusing in/exclusion processes and race relations. According to Michel Foucault (2005), subjectivation is a broad and complex process, involving both the relation of the subject with the regimes of truth that circulate and constitutes itself, as well as its relationship with itself and with others. It is through these processes of subjectivation that we become subject.

The study of the process of subjectivation experienced by Afro-Brazilian people was important to comprehend the effects of the changes that occurred last decades in Brazilian

society. Since the 1970s, a set of political, social, and cultural modifications in race relations began to be developed in Brazil. These changes are related to the problematization of the discourse of racial democracy and the articulation of movements in favor of Black consciousness. Nowadays, the discourse of racial democracy is understood as a myth, a fallacious ideology that became, since the 1930s, the central discourse constituting the Brazilian nation. Based on miscegenation, this discourse historically defends the idea that we are a nation marked by harmonious racial relations, where racism does not exist, different from the USA.

These changes made possible the strengthening of blackness in Brazil. Blackness can be understood nowadays as a space that includes: the narratives assumed by individuals who recognize themselves as Blacks, the dynamics present in discriminatory practices, anti-racism policies, tensions that cross-racial relations and, in general, all movements that involve the Black populations. Blackness can also produce foundational ideologies and myths, to reverse centuries of historical invisibility and to strengthen cultural identity. As shown by Johnson (2003), blackness is performative. Indeed, blackness works as a set of discourses that operate on different front lines, producing regimes of truth and processes of subjectivation.

The blog *Blogueiras Negras* can be considered a productive setting for studying how the strengthening of blackness makes possible Afro-Brazilians recognize themselves as Black in terms of racial identity. Different from other countries, in Brazil, the Afro-descendants, especially with clear skin, can navigate in social positions without necessarily consider themselves as Black. However, once the person develops Black consciousness, the way how the person sees itself and many situations where he/she is involved receive another perspective. In this process, inequalities and racial discrimination become explicit, even in experiences of the past.

When the narratives published in the blog describe discriminatory experiences lived by Black women, the school is one of the settings that more appear. Brazilian researchers such as Gomes (2002; 2008), Silva (2015), Silvério (2015), Oliveira and Abramowicz (2010), and Munanga

(2015) have argued that multicultural education has not been working as necessary at schools. Race relations is a challenge when conflicts between Black and White children occur, and teachers feel unprepared to manage it. Black women tell us in their narratives how these events occur. Thus, the narratives bring us a privileged perspective of race relations because the victims of discrimination are the ones who report the experiences and their effects.

These experiences with racism within the school incite us, as educators, to think about teaching in contemporary schools. Since the publication of the federal Law 10.639, in 2003, that demands the teaching of African and Afro-Brazilian history and culture in the curriculum, educators and researchers have been studying the best ways to work with these themes at school. Black women offer us many clues to avoid the scholar reproduction of the racial exclusion present in the society.

Analyzing the research data, some questions have arisen: What makes the school to be seen by Black women as a discriminatory space? Which elements about curriculum and teaching do these experiences put into play? Has the federal Law 10.639 helped to change this reality told by the authors? How can we become teachers and citizens more sensitive with to other's experience? How can autobiographic narratives help us with that transformative attitude?

In addition to the investigations carried out in Brazil, some elements of the Critical Race Theory (CRT), a theoretical field developed in the USA (Ladson-Billings & Tate, 1995; Delgado & Stefancic, 2001), can contribute to problematizing what (and how) we are doing inside our schools.

The remainder of the paper is organized as follows. The second section describes the methodology developed during the research with autobiographic narratives of Black Women. The third section presents some fragments of narratives related to the school and analyses the research data, connecting the narratives with academic discussions in the multicultural education field. Section 4 demonstrates the potentiality of autobiographic narratives written by Black women for more inclusive education. Finally, section 5 concludes the paper, claiming the possibilities to develop other subjectivities

and racial relations at school, both for teachers and students.

2. Working with Black Women Narratives: Methodology

Blogueiras Negras is a platform of publication made by, for and about black women, in affirmative character. However, we are much more than that. (FAQ - Blogueiras Negras, 2017)

This section describes the field of the research and the methodological steps developed during the investigation. Firstly, it is essential to understand how the research data is composed and the characteristics of the autobiographic narratives. Secondly, the conceptual tools chosen for operating the analysis are presented. Finally, the section brings a brief discussion about the ethical concerns of the research.

The term blog means a junction of a network (web) with logbook or systematic record (log). The Blogueiras Negras' (BN) project was created in 2012, by a group of Black women whose main objective was to give visibility to the writing of this group. The BN identifies itself as a virtual community which only Afro-descendant women can belong and publish. The facilitators of the blog are Black women responsible for selecting the texts, performing the editorial review, and feeding the blog, as well as mediating the debate in the discussion group. Texts can be shared on other platforms such as Facebook, Twitter, Google+, LinkedIn, Telegram, and WhatsApp. There is an option to subscribe by email so that the follower receives a notification each new post. The first publications are available since March 2013, and every publication can be accessed by categories, divided by keywords, resulting in more than 30 options. Each text presents a photograph or image suggested by the author.

The empirical corpus of the research was composed of 36 autobiographical narratives published between 2013 and 2016. The authors are free to create their profile. Mostly Black women give information about them, such as age, occupation, city of residence, and identity positions. Except for the fact that all authors are Afro-Brazilian women, there is a diversity of profiles, social classes, and personal experiences. The authors live in at least 13 different states.

Most Black women are undergraduate students (15) or have completed higher education (14), and four are graduate students or already have a master's degree. Almost half of the authors (17) are teachers or students to become teachers, which is a relevant element for this research. The main age group is between 20 and 30 years old.

The narratives highlight sexual and gender diversity, and there are distinct ways of how Black women are positioning themselves as Black feminists. Several authors also write for other blogs and participate in Black feminist communities. After careful reading, five categories were created considering the most productive and repeated elements in the texts: a) childhood experiences/family racial education; b) schooling experiences; c) Black identity; d) participation in social movements, and e) subjectivation process. In each of these categories, excerpts of the narratives were selected, always with the care of identifying the authors.

According to Claudinin (2013), the experience is the central element of research based on narratives because "narrative inquiry is a way of studying people's experience" (p. 38). There are several ways of interpreting narratives, according to the theoretical perspective chosen by the researcher. In this research, Foucault's (2009) notions of discourse and self-writing work as primary tools in the analysis of the autobiographic texts. In order to understand Foucault's discourse, it is necessary to take language as constitutive of our thinking and as the meaning of how we understand our experiences and the world (Veiga-Neto, 2007). There is nothing behind what is said, and the subject who speaks is never outside of the discourse, which he/she contributes to build. Indeed, an analysis of discourse, according to Foucault (2009) asks for the procedures of control, delimitation, and veracity of the discourse.

Self-writing is a concept that guides the reading of autobiographical narratives and the analysis of the processes of subjectivation. This is a process that Black women show to produce in the movement that becomes Black women. While readers, writers, and activists of social movements, these authors are changing the moral codes that socially conduct them. Therefore, self-writing as a theoretical tool allows the researcher

to identify the relation of the subject with itself, others, and with the blackness, in the process of ethical elaboration. (Foucault, 2014)

Although the access to the narratives is free, the fact that *Blogueiras Negras* is a virtual community exclusive for Black women has generated many questions. Is the free access of the blog enough to research its content? As a White woman who does not participate in this intersectional space, would have the researcher enough ethical care for working with stories of these Black women? How could my identity interfere in the data analysis? The fact of recognizing myself as an activist for racial equality is enough to manage the sensitive situations told in the narratives? These questions were considered during all the research, and the project was sent to the ethical committee. Although the reflection about researcher identity is always present, this investigation promoted many concerns, sometimes difficult to manage.

Independent of the racial identification and level of engagement with the virtual community, the position of the researcher always implies a different perspective from the authors of the blog. As Fonseca (2010) suggests, it may be necessary that we develop in our researches an ethic of discomfort. The exercise of vigilance and careful reading not only with the narratives but with the work develop by Black intellectuals have contributed to the constant reflection in this research. For this reason, we consider fundamental to recognize our position of speech (Ribeiro, 2017), but without making this position prevent us from thinking ethically and, at certain moments, problematize this place.

Although only Afro-Brazilian women can post on the blog and participate in the forum, everyone can have access to the publications. Paying attention to the *Blogueiras Negras* standards, an email was sent to the facilitators of the blog informing about the research. Additionally, in the writing of the research, authors are always identified by their full name, with the date of publication. This form of presentation follows the politics of the blog, which privileges the authorship and demands its maintenance.

In the next section, the narratives about schooling are presented and analyzed.

3. Becoming Black Women: The Process of Subjectivation and the Narratives about School

The redefinition of the self through the writing of autobiography places power into the hands of the writer to define who she is and to share her self-identity with the readers. This is the initiation of the changing of global societal views of Black women. (Harris, 2005, p. 38)

Why does Harris (2005) affirm that self-writing could promote another point of view of Black women? That is one of the questions that have conducted the discussions in this paper. The articulation purposed in the research made it possible to identify a powerful process of subjectivation. This subjectivation is triggered from the moment the Afro-descendant woman recognizes herself as Black and begins to see identified with blackness. The connection with blackness occurs especially through the Black Feminism.

The Black Feminism began in the USA (Black Feminist Movement) as a response to the Black Liberation Movement and the Women's Movement, both movements that did not delegate the necessary attention to Black women. In Brazil, historical records point to the participation of Black women since the first phase of the Black movement, in the 1930s (Domingues, 2007). However, it was in the 1980s that activists sought to develop their path of political resistance (Nepomuceno, 2013), creating Black feminist organizations across the country. Since that time, Black activists "are accused of fragmenting both women's struggle and the fight against racial discrimination" (Nepomuceno, 2013, p. 400), but there is no doubt that a specific agency has ensured greater visibility for these groups.

The Black Feminism articulates gender and race; thus, intersectionality is an important concept. According to Crenshaw (2002), the intersectionality is productive insofar as it makes visible issues that cross-gender, race, or other identity markers. Gender and race produce, working together, multiple forms of discrimination against Black women therefore is not possible to isolate one or another concept. As a result, Black Feminist Thought has become a significant field. Collins (1990) points out that this

is an intellectual movement focused on Black women that seek to influence a growing number of activists. This is also a way of valuing the intellectual leading of Black researchers, considering that their production has direct effects on Black feminist collectives. Thereby, Black Feminism has been a fundamental field for the strengthening of blackness.

The narratives analyzed are strongly influenced by the Black Feminist Thought. In *Blogueiras Negras*, it is possible to see that the movement to become a Black woman is both individual and collective. The transformation of the self depends on the constant presence of other Black women, taken as a reference in the process of self-constitution that is complex, continuous, and involves intense learning. Therefore, *Blogueiras Negras* is understood as a political and resistance space, but above all, an educational one.

The autobiographic narratives about trajectories and school experiences are very striking. Although they show a frame of Brazilian schools that meet what the researchers developed in Multicultural Education field have been discussing, for those who defend the importance of the school and work with Multicultural Education it is a frustrating scenario. The excerpt of the narrative below illustrates this context:

Sometimes I find myself remembering my childhood and [...] I think how difficult it was to be black inside the school. An environment that does not accept differences, that the different is seen as unequal, in which I was often harassed by other children. [...] Going to school became an act of courage, mainly because all my pain was silenced, when I realized that complaining to the teacher did not work, I only had to cry for my mother at home. (Ana Carolina Reis, personal communication, July 18, 2014)

Ana Carolina Reis recalls the difficulties experienced within the school. In addition to the forms of violence suffered, the author felt helpless by the teachers, thus going to school became an act of courage. Black women need courage many times, not only because they have faced difficulties while students but because they are adult women that report their experiences and encourage other Black women to the struggle. It is frequent in the narratives the violence acts

described by Ms. Reis. Many times, conflicts provoked by an offense or that end in a racial offense are naturalized within the school. Until the conflict results in physical assault, teachers and pedagogical staff frequently do not interfere. The discrimination reported by the authors appears to be closely associated with nicknames or dialogues that assaulted them when they were girls.

When we get to school, we start worrying about having our friends, we want to be part of a group, and then we discover that everything is not so easy as it seems. Some kids do not want to be around us, touch us, hug us, some kids laugh of our hair, our noses, they say we are ugly, sloppy. (Patrícia Anunciada, personal communication, December 17, 2014)

The offenses described in the excerpts reinforce, on the one hand, the need for Black children's self-esteem and, on the other hand, the need for a pedagogical work that manages the conflicts and has an inclusive attitude related to racial relations. These questions have been widely addressed by the Law 10,639/2003. As mentioned before, it became mandatory the teaching of Afro-Brazilian and African history and culture in all educational institutions of Brazil. The guidelines for the implementation of the Law indicate the need for a positive conception of Black culture and the African continent. This conception should help to develop a positive identification between Afro-Brazilian children and youth with their ancestry. (Mec/Seppir, 2004)

Regarding racial conflicts, experts suggest that educational institutions should increasingly pay attention to the way how students build a relationship (Gomes, 2008). It is common for us to think about race relations as established between White and Black students with dark skin. However, it is not only in the most profound difference in the skin color that the conflicts occur. The belief that the good and the beautiful are in the European phenotype ends up regulating relationships from childhood. Once children can identify phenotypic differences, White and Black children are also able to rank differences according to social codes. (Oliveira & Abramowicz, 2010)

Throughout the schooling experience, the strategies applied by Black women as a way of

survival were diverse: humor, the company of White colleagues, indifference. The relationship with itself is produced in the constant struggle to endure the humiliations, expressed through the shame of self, the denial of your color, or the jokes about herself and other Black girls. Unfortunately, it was at school that many of these excluding forces developed more intensely and persistently. A place for excellence for teaching and learning, like the school, has the legitimacy to assert the discourses that put into circulation.

The narratives are impressive not only for bringing the reports as mentioned earlier of discrimination but also because the way as teachers are mentioned by the Black women. The teacher's absence of incisive action face to the processes of exclusion and invisibility should be seen as an alert. The following situations demonstrate that actions:

The teachers did not take me into account [...] in this school, I went through several violent experiences, which started from the pre-adolescents. A group of girls put chewing gums in my hair, my hair curled, my hair CRESPO (at the time I kept my hair always tied)... The teachers never thought I would be the "outstanding" student or that their technical methods of teaching would develop the best results; they always seemed to be surprised by any successful response. However, they did not exalt the good results. (Raescla Ribeiro de Oliveira, personal communication, September 22, 2016)

According to the age of Ms. Oliveira and authors in general, the school experiences reported by Black women probably occurred before the promulgation of Law nº. 10,639/2003. Until this period, the discussions about the education of racial relations were incipient and practically nonexistent in the school curriculum. Considering the history of Brazil and the diversity that marks the Brazilian population, it is disappointing that specific legislation is necessary to make the themes like the history of African and Black Brazilians, Black culture, and the fight against racism part of the schooling.

However, teaching materials and specific teacher training courses began to arrive at the public educational institutions only after 2003. This picture tends to change with the

understanding of the adverse effects that Brazilian history has built on the Black bodies, making possible the break down with this homogenous vision and, therefore, prejudiced concerning the Black population. (Silva, 2015)

The study here presented has shown that some Blogueiras Negras authors are helping to change the reality of some schools. The work with the autobiographies allowed to visualize attention towards the school. Beyond criticizing and denouncing racism in the school space, Black women emphasize the need for another pedagogical approach to multicultural education. The profiles show that at least half of the authors have chosen the teaching career. It is interesting to understand, therefore, how the process of identity subjectivation crosses the professional exercise and constitute the teaching of Black women. Some examples are presented below:

I would like to speak not only of my experience as a black woman but of many of my students who are going through this painful process of building their identity. Since we were a child, we are accustomed to lack references of successful and well-represented black people, whether in magazines, newspapers, movies, drawings, comics, and often even in our family and neighborhood. How many of us did not learn at home that our hair takes much work and that the most natural solution would be to tame the volumes or straighten out the hair? (Patrícia Anunciada, personal communication, December 17, 2014)

Today, as a Black woman and teacher, I see that I can make the difference in the life of every Black person without perspective. (Glauce, personal communication, January 28, 2015)

Patrícia Anunciada reports that her students are experiencing the same difficulties she faced: the lack of positive identifications with her race causes self-esteem problems. Connecting her story to the story of her students, the author creates alternatives for providing, as a teacher, positive Black references in her classroom. In the same way, Glauce sees herself as a teacher able to offer other experiences for her students.

The commitment of Black women who opted for teaching with multicultural education can be justified by at least two reasons: a) most of the authors who publish in the blog are engaged in

social movements and activism of Black feminism, thus they share the political demands; b) the protagonism of Black teachers is directly linked to the promulgation of federal Law n. 10,639/2003, one results of the Black movement historical struggle. The autobiographical texts of the Black teachers offer a privileged vision of how the movement to become a Black woman and the political action of these professionals conduct the constitution of their teaching.

Many Black teachers are protagonist in inclusive education because they know more than anyone the importance to provide an environmental that recognizes all students. Stubbs (2008, p. 8) describes inclusive education as “a wide range of strategies, activities and processes that seek to make a reality of the universal right to quality, relevant and appropriate education”. In this case, inclusion also means to consider the difference and problematize the exclusion provoked by this difference. Black teachers have a specific view for Black students and race relations.

According to some American and Brazilian scholars (Casey, 1993; Achistein & Ogawa, 2011; Beauboeuf-Lafontant, 2005; Silva, 2011) many of these women have the social commitment to an antiracist education in the centrality of their teaching. Nevertheless, these narratives cannot be generalized or indicate a unique way of understanding the teaching of Black teachers in Brazil. Gomes's (1999) research, conducted in the 1990s, showed that Black teachers felt isolated, had difficulties working with the racial conflicts of daily school life and did not necessarily express a historical-political reflection. Three decades later, racial discrimination and challenges continue, but we progressively have more access to knowledge and discussions for fighting against racism.

On the other hand, the isolation of Black teachers pointed out by Gomes (1999) may continue to be a severe problem. In schools where these professionals are the minority, as well as there is no commitment to antiracist education as part of the pedagogical proposal, Black teachers tend to feel alone. It happens especially when they realize that they are the only ones who are sensitive to racial conflicts. The excerpt below attests this feeling:

I am a Black woman who was looked with astonishment when for the first time I entered in the teaching room. That was questioned about the teaching in the classrooms, silenced in meetings, and pedagogical meetings. The one who was called inexperienced. (Eliane Oliveira, personal communication, September 11, 2015)

The excerpt highlights the difficulties of the early years of Eliane Oliveira's career, which in addition to all the challenges as a beginner teacher, she is continuously questioned by the color of her skin. Achistein and Ogawa's study with non-white beginning teachers working in American urban schools reports that these teachers were "motivated by their deep sense of commitment to the youth of color, which was fueled by the teachers' personal experiences and professional preparation" (Achistein & Ogawa, 2011, p. 67). However, this commitment in many cases resulted in isolation:

The empathy of teachers of color for students of color, which was reported to be rooted in a common experience, resulted in teachers feeling isolated, having few colleagues with whom they shared the same orientation toward students and being excluded from certain professional and social encounters that could foster a sense of belonging, help their teaching, and impact organizational decision making. (Achistein & Ogawa, 2011, p. 81)

When the university approaches the racial theme and discusses with the future teachers the importance of inclusive education, Black women also feel contemplated, contributing to their commitment to teaching. In this context, inclusive education can be understood as a set of social, cultural, and educational practices that focus on the subjects and groups that historically have experienced processes of exclusion. It also is a movement that struggle for the right of these subjects to self-represent and to accomplish equal opportunities. (Lopes & Fabris, 2013). Rozana Ribeiro illustrates that support from the university:

Something that gave me support at this stage is my undergraduate course in Pedagogy, which deals with all this, valuing the subject's identity, understanding the phases and needs of the child, the power of the school to build the

identity of the child. (Rozana Ribeiro, personal communication, August 2, 2016)

For Rozana Ribeiro, the teacher license course has offered conditions not only for her teaching to be committed with multicultural education, but the course also has helped in her constitution as a Black woman. Narratives like this allow us to visualize the importance of spaces of teacher training that approach the themes of identity and difference, considering the singularities of the subjects that are being constituted in these educative spaces.

The research shows that recognizing oneself as a Black woman produces an essential change in the subjectivation, which interferes in the teaching. With the process of subjectivation, the commitment to antiracist education becomes stronger. The authors make the blog a place for telling stories and claiming for the right to the singularity. These Black women demonstrate to be choosing the field of education for developing a work committed with multicultural education and inspired by their life experiences. Aware of the implications of racism on children and young people's life, Black teachers have been fundamental for advancing researches and for the dissemination of pedagogical practices that value the self-esteem of all children, especially those who still suffer because of their race/ethnicity.

Similar results were found in the studies conducted by Casey (1993) and Beauboeuf-Lafontant (2005). Working with narratives of American Black teachers, Beauboeuf-Lafontant identified three principles. First, "the women located themselves in traditions of female activism and derived much knowledge, fortitude, and voice from foremothers". (Beauboeuf-Lafontant, 2005, p. 440). It means that Black teachers do not consider themselves the first or the last to develop a specific work, but they are part of a culture that educates with affection and competence. Second, the care and the attention developed by Black teachers that can be considered a political attitude, since they are aware that there are few places in which children from marginalized spaces are embraced. The third principle is that Black teachers see themselves as subjects opened to continuous transformation. "They located their competence and effectiveness

in their efforts to seek improvement and growth". (Beauboeuf-Lafontant, 2005, p. 442)

As we have seen throughout this section, Black teachers have much to tell us. When experiencing the process of subjectivation, Black women who chose for teaching tend to develop a potent job with their students, a job articulated with the power contained in the ethos that constitutes them. The result is a commitment to the transformation of racial relations in the school space. Black teachers know precisely what racial discrimination means, so they are committed to inclusive education and struggle for multicultural education to become part of the school curriculum.

Considering individual and collective experiences, we become teachers in different ways, but always in relation with ourselves and with others. It is essential that the responsibility should not be restricted to Black teachers. Indeed, their experiences as Black women and educators might influence all professionals, making the right to respect and singularity a task for all. If we stand side by side, we can certainly do much more.

4. The Potentiality of Autobiographic Narratives for Inclusive Education

After presenting the results of the research developed with autobiographic narratives written by Black women, to discuss its potentiality of is the primary goal of this paper. As we have seen in the last section, the narratives published in *Blogueiras Negras* make evident how racial relations are constructed in Brazil and how Black women are managing with the experiences they have been through. Thus, these are some arguments for explaining the relevance of this blog in the research.

This section defends the potentiality of autobiographic narratives, indicating three possibilities by its appliance. First, working with narratives that circulate in virtual communities such as *Blogueiras Negras* can contribute to the empathy and the necessary commitment for inclusive education. Second, storytelling and the use of historically excluded voices are crucial strategies for Critical Race Theory - CRT intellectuals. It means that CRT may offer productive tools for our work in Multicultural Education field. Third, providing the writing of

narratives in our educational institutions, we might develop other subjectivities at school.

According to Harris (2005, p. 47), "the use of autobiography in multicultural education is a concept that is rapidly taking hold in teacher education" especially because it helps students and teachers to reflect about themselves. Furthermore, autobiographies enable students and teachers to know stories of life very different from itself, and it is a principle to develop respect for to other's stories. "Autobiography is a way of introducing students to different cultures when the students are required to write about themselves and to share those writings with their teachers and classmates" (Harris, 2005, p. 47). This movement includes writing and sharing experiences that sometimes produce pain and anger. Recognizing their feelings can be the first step for dealing with these effects.

Scholars affiliated to the CRT have shown strategies that could be applied to the Multicultural Education in Brazil. The CRT was born among American legal scholars and brought to the Education field in the 1990s (Ladson-Billings & Tate, 1995). The CRT places race and racism in the centrality of the discussions. This positioning makes it possible to analyze the inequalities that characterize the school experiences of non-white students (especially Blacks and Indigenous people), especially when related to the right for quality education and curricular organization. Additionally, CRT in Education not only problematizes the celebration of diversity but also suggests themes and strategies that might be more explored in research and pedagogical experiences, such as intersectionality, storytelling, and the racial positioning of the teacher/researcher.

Displaying how challenging can be the lives of some groups and how much racial relations matter to non-White subjects is one of the goals of CRT. Giving materiality to the experiences of African-Americans is one of the strategies employed by writers linked to this field. In this way, autobiographical narratives, reports of everyday situations, and even fictitious stories are useful resources for members of CRT. These are strategies to put racial themes in the centrality and challenge the relations of domination, where

racism persists. As Ladson-Billings (2015, p. 20) points out,

Stories provide the necessary context for understanding, feeling, and interpreting. The ahistorical and a contextual nature of much law and other “science” renders the voices of dispossessed and marginalized group members mute. In response, much of the scholarship of CRT focuses on the role of “voice” in bringing additional power to the legal discourses of racial justice.

For this purpose, chronicles, narratives, poems, fiction, and other literary genres are used, including stories by the own author. Thus, the CRT also challenges its authors to reflect on their subject positions. In this case, the racial belonging of the writer does not only matter but must be considered in his writing. For White authors, it is not a question of “giving up” their whiteness (as if that were possible!) but a requirement for reflecting about their privileges. Moreover, authors affiliated to CRT recognize that racial issues across our work and our daily lives. In general terms, CRT scholars are committed to social justice and willing to challenge the status quo. As a consequence, CRT can contribute to problematizing what (and how) we are doing inside our schools.

Finally, it is valued to highlight the importance of producing autobiographical narratives with teachers and students, leading them to reflect on their life stories and the experiences of their colleagues. When we do not ignore the cultural background of our students, it becomes possible to develop other worldviews and to problematize the truths that position certain groups as excluded. As Ladson-Billings (2009, p. 109) emphasizes, “I admire the strength and elasticity of students who continue to come to school and participate, even when their intellect and culture are regularly questioned.”

5. Conclusion: Developing Other Subjectivities at School

This paper sought to discuss some results of an investigation developed with autobiographic

narratives, written by Brazilian Black Women and published in a blog called *Blogueiras Negras*. After analyzing the data, it was possible to identify the productivity of the narratives written by Black women about school. These narratives are formed mainly by painful memories of racial discrimination in educational settings.

The school is an institution that produces subjectivities that historically served the purposes of the Modernity (Veiga-Neto & Traversini, 2009). Traditionally, the Brazilian curriculum is organized considering mostly European references where Whiteness is the regular subjectivity. Even though we have a federal Law that requires the inclusion of history and culture of other groups – especially Afro-Brazilian and indigenous –, teachers do not know how to do this change. Black women narratives indicates the problems of the school and help us to problematize the curriculum.

We believe that the school nowadays can become a space and a time for the fabrication of contemporary subjectivities, which are based on respect and singularity. Gert Biesta (2006) shows that the key to education continues to be the relationship with the other, but we need to be able to review the relationships established within the school, mainly because these relationships have consequences that go beyond this space.

There is no doubt that all of us, White and Black teachers, have much to learn from each other. Together, we can work to change the racial relations within the school. Although the school has no conditions to transform the society alone, other subjectivities can be produced so that Black subjects do not depend on the process of subjectivation to problematize the violent forms of education received. The task before us is long and complex but making visible the experiences that constitute the different subjects we can begin the long journey towards other educational practices. The result, we believe, is more inclusive education.

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THEORETICAL FRAMEWORK FOR RESEARCH ON MATHEMATICAL OLYMPIADS IN LATIN AMERICA

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KEY WORDS

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ABSTRACT

This theoretical framework is intended to serve as guide to research on national Mathematical Olympiads in Latin America. Research with the goal to elucidate critical factors involved in the existence and results obtained by Latin American teams in the International Mathematical Olympiad (IMO) and other international contests, may find a stepping stone in this framework and the references cited in it. From the way local committees see themselves and their indicators for success to the feedback subsumed in the IMO results, different comparable metrics for success must be developed to understand the specific challenges faced by these organizations and the goals set by themselves and the educational communities in their own countries. As for Latin American countries the IMO is not the only competition they attend or their single metric for success, reference to the IMO is provided as the evolving opportunity leading to the creation of local Olympiad committees, the committees this framework presents as an opportunity for research and understanding of the search for talent in developing countries. As a way of closing the document, a few questions are proposed, offering both quantitative and qualitative research areas and with the possibility to reach findings helpful for those organizations, for the school students in their respective countries, and for similar organizations in other countries.

1. Introduction

The Mathematical Olympiad movement grew worldwide at an amazing rate over the last century. In the words of Kenderov (2009), “It would not be an exaggeration to say that the rise and development of Mathematics Competitions is among the characteristic phenomena of the 20th century” (p. 17).

Tracing the history of the International Mathematical Olympiad (IMO) over the last sixty years provides strong proof of that growth. There was no IMO by 1957, although according to Kenderov (2006) the idea of organizing it for the first time was already under discussion; furthermore, there was no “International Mathematical Olympiad” name, as it was first used in 1959 before the first IMO was held (Turner, 1978). By 1967 the IMO was already on its ninth edition, hosted by the former Yugoslavia, with 13 participating countries. A decade later, in 1977, the IMO reached 21 participating countries and by that time 23 countries in total had attended at least once the contest. Ten years later, the 1987 edition hosted by Cuba received 42 participating countries, twice 1977’s number and more than three times that of 1967. Jumping forward another decade, Argentina hosted the 1997 IMO with 82 teams in contest, nearly doubling again the number. The 2007 IMO, held in Vietnam, received 93 teams—94 according to Kenderov (2009)—, not increasing as much as on the previous decades, but nevertheless, still growing. For the current year, 2017 IMO, hosted by Instituto de Matemática Pura e Aplicada (IMPA) in Rio de Janeiro, Brazil, just announced—June 29th—through social media, that there are 112 countries registered for the competition, breaking the record set just one year before with 109 participating countries attending the 2016 edition held in Hong Kong (IMO Advisory Board, 2016b; The 58th International Mathematical Olympiad (IMO 2017), 2016). The short review done here shows steady trend for increase in the number of participating countries, with more than half of all world’s countries attending in the last few years.

Almost in every case, participating countries in the IMO choose their contestants through a

national competition and create associated training sessions to get those contestants ready to carry their country’s name to the IMO. The increasing numbers for participating countries in the IMO are simultaneously cause and consequence of an increasing network of local committees organizing mathematics competitions, and in that sense it is proof of the existence of those local committees and their will to be recognized worldwide. The reasons for the importance of those local committees are at the base of this framework, and the critical factors for their success are within the expected outcomes of future research.

2. Theoretical Framework

“The International Mathematical Olympiad (IMO) is nowadays the most important and prestigious mathematical competition for high school students” (Berinde & Pacurar, 2009, p. 15). Those words summarize the way people involved in the Mathematical Olympiad movement see the IMO, and some paraphrasing of them can be found in almost every piece about the contest (Berinde & Pacurar, 2009; Djukic, Jankovic, Matic, & Petrovic, 2006; Kenderov, 2006; Turner, 1978; Verhoeff, 2011). Its importance within the community provides support for the use of IMO results as a preliminary indicator of success for those national organizations, and the inclusion of the IMO as a motivating factor for the growth of national Olympiad organizations.

However, the goals for the IMO, and for mathematics contests in general, are beyond the plain competition and the crowning of a winner, it can be said that it goes beyond the participating teams and even the participating countries. As stated in the IMO Regulations (IMO Advisory Board, 2016a)

1.4 The aims of the IMO are:

- to discover, encourage and challenge mathematically gifted young people in all countries.
- to foster friendly international relationships among mathematicians of all countries.
- to create an opportunity for the exchange of information on school syllabuses and practices throughout the world.
- to promote mathematics generally.

Analyzing these aims, there are three key components to be highlighted: intention for a fully global reach, sense of community, and emphasis on both mathematical talent and knowledge; none of the stated aims point to the contest itself or its results, making competition the vehicle for bigger goals.

Global still a long term goal for the IMO, with 112 participating countries in 2017 still far away from the 193 member states of the UN (United Nations, 2016). However, numbers are impressive from the chronological perspective. According to different sources, the first contemporary mathematical contest was the Eötvös competition beginning in 1894 (Kenderov, 2006, 2009; Turner, 1978; Verhoeff, 2011), and as of December 2016 there were about 130 countries in the IMO database—taking out those countries that no longer exist (IMO Advisory Board, 2016b). On average there was at least one additional country involved in mathematical contests every year. There is no reason to assume there are no mathematical contests under IMO-like formats in countries outside of that list, but taking the IMO as reference 130 is a well-supported estimate, about two-thirds of the countries in the world.

The sense of community in these competitions is addressed from different viewpoints. Verhoeff (2011) makes a case for the value of the IMO proposing as one of the most relevant facets of each year's competition the sense of Community before and after the tests, both between team leaders and between students. Kenderov (2009) provides an historical overview of the first 25 years of the World Federation of National Mathematics Competitions (WFNMC), the organization overseeing the vibrant community forged around the IMO and mathematical contests in general. The WFNMC is so linked to the IMO that their 8th conference will be held right after 2018 IMO (World Federation of National Mathematics Competitions, 2016). The importance of the WFNMC to the international mathematical community is beyond doubt, for example it is recognized by the International Mathematical Union (IMU) as one of the International Commission on Mathematical Instruction (ICMI) Affiliated Study Groups since 1994 (Bass &

Hodgson, 2004). Another way the community has been created and developed around mathematical contests is through the creation of regional competitions, sometimes considered small communities by themselves (Kenderov, 2006); some of those regional competitions are IMO spin-offs, but some others have developed their own procedures.

Talent search in mathematics is probably at the center of the whole idea of mathematical contests, being the aims of the IMO just an example of that. Campbell and Walberg (2010) include the following as common ground for academic competitions:

All competitions operate under a series of assumptions that constitute a distinctive rationale:

1. Children with talent need to be identified early.
2. Competitions are needed because many schools do not have the differentiated curriculum or the resources that are needed to challenge extraordinary students.
3. Contests will attract participants with extraordinary talent.
4. Contests will motivate the early development of talent.
5. Once developed, this talent is expected to contribute to society. (p. 8)

Furthermore, the community surrounding mathematical contests of this kind traditionally believe on the need to develop young talent, summarized in the phrase “Unlike other natural resources, such as mineral deposits, which remain preserved for the future generations, if undiscovered and unused, the talent of a young person is lost forever, if it is not identified, cultivated, and employed properly” (Kenderov, 2006, p. 1588). This belief places the efforts made by the national mathematics competitions at the service of the development of scientific thinking worldwide through the discovery and nurture of young talents.

Studies on the impact of mathematics competitions, including the IMO, on talent search and development are flattering to their value, to say the least. Campbell (1996) highlights the value of finding talented children at early age and the positive results brought by both the American Mathematical Olympiad and the Westinghouse Talent Search in the United

States. In subsequent analyses, Campbell and Walberg (2010) also include data from the physics and chemistry Olympiads, and report that the largest percentage of students chose career paths related to their respective Olympiad (mathematics, physics, or chemistry) and the largest percentage of students completing their doctoral studies were former winners of the mathematical Olympiad. Furthermore, Subotnik, Miserandino, and Olszewski-Kubilius (1996) in their conclusion state “Clearly, individuals with special interests or talents in mathematics need to be identified as early as possible and supported and challenged by their teachers throughout their formal school experience” (p. 570), and put special emphasis on the positive effects preparation for the IMO has on achievement and life choices. Finally, Bicknell (2008) speaking about mathematics competitions in a broader sense emphasizes the role of competitions and challenges on helping students develop skills such as self-directed learning and co-operative team work.

This dissection of the aims of the IMO, inherited by most of the local committees in charge of national and regional contests, is also part of the required support for the selection of Latin American national mathematics Olympiads as the subject of study.

3. Why Latin America?

Latin American countries have a wide number of characteristics making their case simultaneously special and relevant.

On one hand, together with Spain and Portugal, they make one of the most widely known regional communities in mathematical Olympiads, all around the Iberoamerican Mathematical Olympiad (OIM, acronym from Spanish). The OIM, created in 1985 by the chairpersons of a few local Olympiad committees with special mention to the leadership of Mary Falk de Losada, begun—and still runs—aiming for two main goals: first, to help local committees on providing their best students with opportunities to train and prepare for the IMO; second, to open the space for local committees to share knowledge and experiences allowing them to learn from others. The OIM and the IMO share

almost the same official aims and goals as well as a common understanding related to the importance of reach, community, and mathematical talent and knowledge. The following is a translation from Spanish:

The OIM is a competition among young students from Iberoamerican countries, with the aims to:

- To promote the study of mathematics in the Iberoamerican countries.
- To find and encourage young talents in the Iberoamerican countries.
- To sponsor friendly relations among students, professors, and teachers of mathematics in the Iberoamerican countries.
- To create an opportunity for the exchange of educational experiences among mathematics educators from the Iberoamerican countries. (XXXI Olimpiada Iberoamericana de Matemática 2016, 2016)

The OIM quickly got to be the meeting point for national mathematical competition organizations. Less than 10 years after the first OIM was hosted by Colombia, all Iberoamerican countries were, to some extent, involved in the OIM. Countries sometimes did not participate each year due to bureaucratic or budgetary issues. Nevertheless, advances in various forms of communication allowed for close ties even with the absence of some member countries each year.

Almost all Latin American countries participated for the first time in the IMO close to the birth of the OIM. México, Venezuela, and Colombia in 1981; Perú, Panamá, and Nicaragua in 1987; and Argentina and Ecuador in 1988 (IMO Advisory Board, 2016b) are just some examples of that, highlighting the importance of the Mathematical Olympiad community in Latin America. The existence of the OIM as a common ground and its continued work as a practical step for Latin American students to reach the IMO provide reasonable support for comparison as shared data is available. Under the umbrella of the OIM other smaller regional competitions were founded, like the Olimpiada Matemática del Cono Sur and the Olimpiada Matemática de Centroamérica y el Caribe, increasing the availability of stepping stones for talented students in their mathematical development, and at the same time providing new spaces for mathematical Olympiad committees to share their

experiences and grow together. Also, as part of the OIM and then the regional competitions that found inspiration in it, the OIM included additional activities and prizes to increase both the sense of community and the motivation for students and teams. As one example, a trophy is given for the country with the most progress in the OIM contrasting with the two previous years. As another example, a recreational team game is organized with mathematical content among teams selected from the contestants but not the national teams divided by country.

On the other hand, Latin American Mathematical Olympiads are a heterogeneous set with common aims but different environments. Some of the organizations are under the protection of national Ministries of Education (i.e. Cuba), others are not (i.e. Panamá). Some have the support of their local Mathematical Society (i.e. Brazil and Mexico) while others do not (i.e. Colombia). Some are working under the protection of public universities (i.e. Costa Rica and Panamá), while others belong to private universities (i.e. Colombia). Still others don't have official support from any specific university (i.e. Venezuela), and the largest ones have continued support from a full university network (i.e. Brazil and México). This complex landscape creates room for each organization to have different ways to reach students, different percentages of national secondary students registered, and different indicators to measure their own success. This large set of complex and interrelated variables provides opportunities for a rich array of both quantitative and qualitative

studies. As a developing part of the world, it is important for Latin American countries to increase their understanding of commonalities as well as differences in local contexts, as the mathematical competitions have proved to be a way to find young talented students and support them on their path towards successful careers in Science, Technology, Engineering, and Mathematics (Campbell, 1996; Campbell & Walberg, 2010; Subotnik et al., 1996).

Taking this theoretical framework into account, here are some questions proposed that may lead to research, and that are fully open for discussion and improvement:

Do local mathematical Olympiad committees in Latin American countries consider the search for talented students as one of their aims? And, if so, what is the definition of talent they use to frame their efforts?

To what extent are the IMO goals adopted by the local mathematical Olympiad committees and what changes or adaptations are made to them when becoming local?

Which factors are relevant for the results and possible success of Latin American countries and their local mathematical Olympiad committees when competing in the IMO?

Other than IMO and OIM results, what is considered by Latin American Mathematical Olympiad committees to be indicator of success?

What ways for sharing experiences and knowledge are local committees in Latin America using, other than conversation during the different international competitions available for them?

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THE GOOD, THE BAD, AND THE UGLY A Broad Look at the Adaptation of Technology in Education

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ABSTRACT

Technology in education is a global phenomenon affecting learners of all ages. The breadth and variety of available tools make it difficult to implement a standardized method for assessing the impact of technology on learning. The lack of a consensus on good and bad practices results in inconsistent application and mixed learning results. This article examines the adaptation of technology to education and the various tools used to enhance learning. A discussion of the advantages and disadvantages of using technology in education, as well as a review of methodologies for evaluating their impact is included. Problems associated with the way technology in education is evaluated are identified. Suggestions for further research to address those problems are included.

1. Introduction: Why Technology in Education?

In my first year of teaching at a university, I had a class of fifteen international undergraduate students. My previous experience was working with professionals that spoke the same language, both lingua franca and technological. During office project discussion, I typically disseminated information to my team in a lecture-type format without having to elaborate on jargon or fundamental principles of the project. During my first university lecture, looking at the blank faces, I realized that lecturing was not the optimal method for disseminating information. Most of my pupils were confused, but for very different reasons. Some were not native English speakers, others came from a culture that prohibited them from asking questions, some had no foundation in the subject, and others were just not interested in the topic because they could not relate it to their lives. Only a small fraction of students that were engaged, dominated the class discussions. To reach every student in the classroom, I altered my teaching approach. Instead of lecturing, I adapted a more personalized approach to disseminating information. This method worked so well that within a few terms my classes were full, with a waiting list. With forty students per class, I found it difficult to dedicate enough time to each group and giving each student meaningful feedback. After a few problematic semesters, I started conceptualizing a technology-based tool that would facilitate learning and be adaptable for the individual's learning style and my primary motivation for exploration of the application of technology to learning.

2. Learning and Technology

Catering to the learning needs of an individual is not a novel approach. Psychologists like John Dewey, Jean Piaget and Lev Vygotsky all emphasized the importance of individual needs in development. Although their particular theories vary, they are considered to be the founding fathers of the Constructivist approach to learning.

Constructivism approaches learning from an individual's framework. The individual constructs knowledge rather than passively absorbing it.

Traditional learning relied on a positivist approach where the teacher was the source of information, and the students are passive learners. Constructivism rejects that notion, stressing that culture, experience, and ability play an essential factor in the learning process. Instead of being told to memorize facts, the learner connects new ideas to their existing knowledge.

I employed a constructivist methodology in my teaching by employing the following strategies:

1. Real-world case-studies allowed students to connect abstract concepts to tangible examples.
2. Students learn about technology, building on their previous knowledge, through technology rich course projects.
3. Students were allowed to select topics relevant to their interests.
4. Working in small groups changed the classroom dynamics and allowed students to
 - a. Cooperate and share ideas
 - b. Support each other
 - c. Present projects to their peers. (Students use language and concepts that are easier to understand to their peers)
 - d. Offer constructive feedback
 - e. Develop, present and justify their project, rather than passively absorb knowledge, which in turn, encouraged deeper understanding and a more meaningful learning experience
5. This process also changed the role of teacher as a facilitator rather than the "go-to person". I intervened only when I saw poor decisions, and I did so by asking questions to provoke thought, rather than telling them what to do.

By applying the aforementioned constructivist strategies in my classroom, I found that its flexibility and individual-focused approach creates a richer educational experience for students. Technology offers multiple ways to connect, collaborate, build community, access information, engage and personalize the delivery of information, facilitating the implementation of constructivist methodology into learning. Using technology is convenient and often more accessible than the traditional methods of learning. It is typical to find students using computers to do their research (Henderson et al., 2015) rather than scanning microfilm or using the Dewey decimal system to find books in the

library. Students using technology benefit from various ways of accessing the learning materials, including videos (Henderson et al., 2015), podcasts (Lai & Savage, 2013), blogs (Garcia et al., 2013), and e-text (Sun & Flores, 2013); giving them greater flexibility in learning, more choices of content as well as how and where they learn (Lumpkin et al., 2015).

The benefits of learning through technology have resulted in significant public investment in their implementation (Latif, 2017). U.S. federal and state governments have invested billions of dollars into various educational technologies (Keegan et al., 2008). Most members of the European Union, as well as other developed nations, have committed millions of euros for the integration of digital solutions (Adkins, 2011). Developing countries are also starting to embrace, or have taken steps into employing technology in learning. For example, Malaysia has invested in m-Learning creating the Open University of Malaysia that caters to learners in remote regions and to those who cannot attend live lectures (Njagi et al., 2015). Researchers from developing nations in the Middle East (Izadpanah & Alavi, 2016), Asia (Joan, 2013) and Africa (Adeyemo, Adedaja, & Adelore, 2013; Mtebe & Raisamo, 2014; Bachore, 2015) are lobbying for their respective nations to invest more into Technology in Education (TiE).

The use of technology in education has attracted researchers to look at this phenomenon. Their work offers insight into a variety of technological trends, benefits, and shortcomings. Unfortunately, there are no standardized methods for evaluating technology, and the breadth and width of topics make it difficult to structure and assess TiE as a whole. The next section will describe the literature selection process, followed by a breakdown and categorization of those works into digestible information blocks.

3. The purpose and methods

The primary objective of this literature review is to explore the current state of Technology in Education (TiE). The initial search in Education Resources Information Center (ERIC) for keywords of "technology in education" and "technology and learning" returned over 50,000

results. To narrow down the results I selected two filters, namely, articles published in the last five years and peer-reviewed articles.

The modified result yielded over 1,000 articles. To keep the materials relevant to the topic of TiE only articles that fit into one or more of the following criteria were selected:

- Advantages of using TiE vs traditional methods
- Application of a tool(s) to a specific discipline
- Teaching methods using technology
- Users of TiE (age, location, discipline)
- Measure/evaluate the effectiveness of a tool or technology
- Perception of (TiE) by students and teachers
- Setbacks in the integration and application

The resulting articles were entered into a spreadsheet and Thematic Analysis was employed to develop categories. Clarke and Braun (2012) describe Thematic Analysis as a "method for systematically identifying, organising and offering insight into patterns of meaning (themes) across a data set" and offer six steps for the process

1. Know the data
2. Generate codes
3. Search for themes
4. Review Themes
5. Define and Name themes, and
6. Produce the report

Thematic Analysis being a systematic approach to data analysis, with theoretical flexibility, made it a powerful tool for generating categories to structure the results. The findings are discussed in the following section.

4. Findings

4.1. TIE is a global phenomenon

The selected articles were in English and came from all over the world. I was especially surprised to find that developing nations were equally active in researching TIE as developed nations. Nearly half of the initially selected (forty-six) articles came from the developing world, demonstrating that institutions and governments

all over the globe see tremendous value in the development and implementation of technology.

Although Spanish Speaking Countries are not well represented in English language literature, during the GKA Edutech conference in 2019 I met many individuals from various South American countries and Spain that were involved with TIE. Based on presentations, posters and conversations, it is clear that for many Spanish speaking nations, TIE is a priority, and educational institutions are integrating TIE into the curriculum on every level.

4.2. TIE is for students of all ages

The majority of the research articles focused on higher education. My suspicion is that this is the case mainly because university students are the most accessible to researchers, and there is more funding available in this realm. Having said that, a surprisingly large number of tools are specifically designed for toddlers and children. There is also a multitude of unconventional ways that technology is used for learning. TIE has also played a pivotal role in lifelong learning. Online tools have opened up opportunities for working adults to learn new skills and fit learning into their busy professional lives.

4.3. TIE is comprehensive

There is a variety of technological tools that cover a broad range of subjects including mathematics, second languages, sciences, arts, writing, engineering, medicine, as well as, aid in learning about other cultures and social diversity. This is significant because of TIE impacts the way people learn in nearly every discipline.

4.4. TIE takes a variety of forms and utilizes multiple platforms

TIE takes many forms. There are too many tools and platforms to mention, the list below summarises the predominant themes in the reviewed studies:

- Discipline-specific applications - include tools that are designed specifically for the subject or tools adapted based on availability or convenience.

- mLearning - the application of mobile technologies for learning, typically applied in settings where access to the institution is cumbersome
- eLearning - courses where the entire learning process takes place online. These often utilise media such as e-text, audio and video to deliver the information and utilise communication tools such as blogs, forums and chat to facilitate communication between students, as well as students and teachers.
- Blended learning - is the mix of eLearning and face to face interaction. At the core of blended learning is Learning Management Systems (LMS). The LMS allows users access to tools, course content, forums, and various other functions that facilitate learning. LMS are discussed in detail in §2.2.4, but it is worth pointing out that they are one of the major themes in the literature and the most commonly used TIE.

From the literature review, it is clear that TIE has a significant impact on and plays a vital role in education. Using TIE to learn is a worldwide phenomenon, implemented for people of all ages in a variety of subjects. The next section examines the positive and the negative aspects of using TIE for learning as well as barriers to implementation.

5. The good

5.1. Real-world relevance

The discussion of the benefits of technology in learning should start with its significance to real-world applications. Technology is part of our daily lives (Camposa et al., 2015). In order to learn through technology, it is essential to understand how to use it. Understanding the benefits of using technology to learn is fundamental to twenty-first-century existence (Scalise, 2016). The goal of education should be to prepare for the future (Sun & Wang, 2014; Kathleen, 2016) and schools have responded by integrating real-world practice into their classrooms. Podeschi (2016) successfully applied this principle to the curriculum for a university

information technology course where students developed a project for a real client. This approach to learning gave the learners hands-on training, problem-solving and experience with client management. Employers look for technological prowess in their staff (Snape, 2017). Tools like email and word processing are standard, and industry-specific tools are an integral part of the working environment. O'Brien and Hamburg's (2013) underlines the importance of the utilization of technology in learning for small businesses to stay competitive. Utilizing web-based resources such as blogs, learning networks, wikis, and video tutorials to solve work-related problems leads to better job satisfaction, acquisition of new skills and better business practices.

5.2. Community building, cooperation, and engagement

Working with other people is another essential skill for the real world (O'Brien & Hamburg, 2013). Technology allows people to collaborate on projects and create meaningful communities that encourage mutual growth (Mukama, 2014). An example of cooperation through technology is Garcia et al. (2013) a case study of the implementation of blogs into the undergraduate curriculum in graphic design and illustration. The researchers examined how students communicate, collaborate and form peer communities. The teachers took a step back from the official role and let the students work together, critique, and learn from one another. Working together via blogs students were able to develop individual skills, critical thinking, and reflection about other people's work, abilities that are sought-after in the classroom and career. A similar study by Lawrie et al. (2014) with over one thousand college students using the iCAS[A1] tool to learn science supports the conclusion that learning through collaborative technology not only an effective pedagogical strategy it also helps develop cooperation skills.

In addition to facilitating learning, collaborative technology can make learning fun and interactive. The integration of media into teaching has yielded positive results. Coskun (2017) introduced interactive learning through video production for seventh-grade science

students. The goal of the project was to get students to collaborate through making videos that explain the scientific phenomenon to their peers. The theme of the video had to be in one of the following formats: news report, symposium or movie. The results were overwhelmingly positive. Students felt engaged, learned from their peers using technology in career-oriented presentation and most importantly had fun. Fun in learning is especially important for younger students, as Camposa et al., (2015) demonstrated in their study of primary students collaborating on an e-book to learn mathematics. Using technology students become active participants rather than passive users. The active role empowers students by letting them become the storyteller, scientist, or researcher.

TiE opens unparalleled opportunities for people to interact and build communities. People with dramatically different, backgrounds, skill sets, and interests can become part of a community through collaboration (Njagi et al., 2015). There are numerous advantages to implementing technology in learning, students work together and learn from each other while being engaged (Kates et al., 2010). By doing so, they build communities (Mukama, 2014). These relationships allow them to learn more than just skills and relevant knowledge, students learn about each other developing empathy and multiculturalism, diversity and grow as human beings.

5.3. Tolerance, Diversity, and Growth

Learning is not just memorization and reiteration of facts from the textbook (Lai & Savage, 2013). Technology facilitates communication and opens the world of diversity to homogeneous groups. Thompson et al. (2013) bridged two isolated communities in the USA and Korea. To get around the language barrier, they used videos and images to visually communicate ideas about their life to learn about each other's culture. Similarly, Grant and Bolin (2016) looked at how students communicate ideas through collaborative videos in a diversity course. Students found content made by their peers more relatable and are easier to digest than traditional academic reading.

Technology is used to build learning communities, support networks, and facilitate

cooperation. Because technology is a global phenomenon, it is accessible and crosses language barriers. Through technology, people can build connections (Njagi et al., 2015) that result in diversity and cultural growth.

5.4. *The right tool for the right job*

The previous section discussed how technology is useful for collaboration and learning. Similarly, a well-designed tool can significantly enhance the learning experience. Subject Specific Tools (SST) have been demonstrated to improve mathematics skills (Brasiel et al., 2016), ability in writing (Bodnar & Petrucelli, 2016), language learning (Bluemel, 2014) and various other disciplines.

Brasiel et al. (2016) compared fourteen mathematical tools employed by the state of Utah. They praised features such as step by step tutorials and real-time feedback. The technology allows students to build knowledge immediately in the process of learning. Whether the user makes a mistake, the program notifies them and gives them tips. If the user cannot resolve the problem on their own, the program walks them through the solution. There is no need to wait for a teacher or parent to explain the error, making it a useful learning tool in and out of the classroom. Additionally, this feature also saves instructor time by not having to review every single assignment. The educators especially valued the ability to supervise their students in real-time, internalized reports and self-assessment tools.

In the developing world, the cost of such tools is prohibitive; therefore, technologies are adopted not explicitly designed for that subject to facilitate learning. Liu and Liu (2013) implemented 3D software for learning geometry to better understand spatial conception. While Ambrose and Palpanathan (2018) utilized Google Docs for Malaysian students learning English, using the program's spell and grammar checking functions, as well as the collaborative element that allows students and teachers to work together synchronously.

5.5. *Convenience, Inclusiveness, and Accessibility*

The previous sections discussed how technology and implementation of discipline-specific tools. This section will focus on multifaceted systems

that combine tools and media to provide unprecedented learning opportunities. The best example of such technology is the Learning Management System (LMS). The benefits of LMS have been extensively studied (Sun & Wang, 2014; Kathleen, 2016) and integrated by many educational institutions (Scalise, 2016; Lai & Savage, 2013).

The LMS is designed to build and deliver online learning environments (Lai & Savage, 2013) for any discipline. Although there are various LMS available (Moodle, Canvas, Blackboard), these systems offer similar features. The LMS serves as an online repository for course-specific digital documents, videos, and audio files. External links to online resources such as journal articles, e-texts, and videos are a common practice. Blogs, discussion boards, and wiki are employed to facilitate cooperation. Quizzes, questionnaires, and games offer interactive options for learning. LMS reduces administrative activity by offering course registration, online tests, and paper submissions. Additional features like timetables, calendars, announcements email and chat, facilitate course structure and communication between staff and students.

Studies of LMS use and perception show that reduced time consumption (Sun & Wang, 2014; Kathleen, 2016), as well as the ability to give/get prompt feedback (Lai & Savage, 2013; Lumpkin et al., 2015), are highly regarded by faculty and students. Access to course material outside of the classroom is another significant benefit (Lumpkin et al., 2015). Studying at their leisure, having the ability to review class material later in the term as well as focusing on listening rather than taking notes was crucial to students (Lumpkin et al., 2015) and helped reduce stress (Hewitt & Stubbs, 2017).

The advantage of learning through media (video, audio, and e-text) is prevalent across all studies. The availability of course content in digital format offers convenience, mobility, and accessibility. Videos were especially popular among students who found them informative and useful (Lumpkin et al., 2015). Additionally, media accommodate different learning styles (Lai & Savage, 2013) and offer accessibility options like computer-generated subtitles for videos and conversion of text to speech for

ebooks (Sun & Flores, 2013) for students with disabilities (Hewitt & Stubbs, 2017).

6. The Bad

6.1. User Tech-Adaptation Level

Given so many positive characteristics, it would be easy to assume that TiE is good. Unfortunately, there are still many problems that inhibit technology from becoming an invaluable part of education. Technology is relevant to the real world, but not everyone is ready for utilizing technology. Individuals have dramatically different skillsets when it comes to using technology. Frequently, it is assumed that students are “power users”, having grown up immersed in technology (Henderson et al., 2015; Thota et al., 2019), but the reality is many do not have enough experience (Sun & Wang, 2014; Hewitt & Stubbs, 2017; Lawrie et al., 2014). The lack of skill causes anxiety and fear (Ouyang & Stanley, 2014) causing students to be disengaged from their curriculum and avoid potentially useful tools. (Sun & Flores, 2013; Izadpanah & Alavi, 2016).

6.2. Lack of Teacher Training

Teacher adaptation of technology faces the same issue. Teachers play a pivotal role in the success of TiE (Thompson et al., 2013; Lai & Savage, 2013; Siraj, 2014). Without training, teachers fail to see the value of technology implementation (Thota et al., 2019), face anxiety (Ouyang & Stanley, 2014) and resist change (Sun & Flores, 2013). The substantial investment of time is a barrier (Hewitt & Stubbs, 2017). Training, as well as the development of online curriculum, is time-consuming and without incentive, which leads to many teachers not wanting to participate.

Although Institutions (Gimeno-Sanz et al., 2014), corporations (Kathleen, 2016) and governments (Latif, 2017) have initiated programs to train teachers in the use of technology and its benefit the methods for measuring the success of these programs are limited. Gimeno-Sanz et al., (2014) and Latif (2016) demonstrated positive teacher reception of educational curriculum but did not follow up on implementation. In order to realistically

gauge the impact on the classroom teaching longitudinal studies of the teachers that attend the conferences would be necessary (Claesgens, 2013).

6.3. Incorrect Implementation

Lack of understanding of the benefits of particular tools or poor planning often leads to the incorrect implementation of technology in the classroom. There are several examples where the implementation of technology offers no visible benefits to the learning process. Garcia's et al., (2013) reasons for the implementation of blogs in an undergraduate classroom are not justified. The researchers open with a dubious statement that “currently the manner in which these tools can be best used to promote teaching and learning is not entirely clear”. They conclude that through the use of blogs students connect and build peer communities, but their findings do not justify that verdict as during the course a significant number of students were disengaged and immediately after the course completion the blogs were disused. Additionally, the prescribed positive aspects of collaboration through blogs such as the development of critical thinking and reflection of other people's work is attainable through in-class group work, why use blogs at all?

Another example is Camposa's et al. (2015) study of children learning mathematics through e-books. While engaging young pupils with math through drawing is innovative, their reasons for using e-books are never transparent. The technological advantages of e-books are searchability, bookmarks, and mobility, none of these applies to kids' drawings.

TiE implementation requires a well-thought-out process. Although blogs may be well-liked outside the classroom, research into perception finds that students dislike using collaborative tools such as blogs (Lumpkin et al., 2015) and discussion boards (Lai & Savage, 2013). Researchers should carefully consider what tool they are using, and why. Implementing technology for the wrong reasons could lead to student disengagement (Lai & Savage, 2013).

Larger institutions face similar issues. Overwhelmingly positive perception of the benefits of technology resulted in large sums of money set forth for its implementation (Lumpkin

et al., 2015). This phenomenon has led to the technological “arms race” among institutions. Schools want to be seen as technologically cutting-edge to attract more students. The unfortunate result is that administrative pressure (Coskun, 2017) and sales pitches drive decisions rather than research and evaluation.

Even popular tools like LMS have mixed reports of usefulness (Lai & Savage, 2013). The implementation of these systems often occurs without any regard to its users. (Lai & Savage, 2013; Sun & Wang, 2014; Magdin & Tur, 2015). Systems design driven by the administration and IT rather than an understanding of user experience inhibits the utilization of these tools (Khan & Khader, 2014).

6.4. It is Personal

There is also an abundance of personal reasons why technology may fail as an educational tool. Boredom and distractions (Brasiel et al., 2016) play a crucial role in engagement. Parents may restrict access to online tools due to concerns about inappropriate material or bullying (Brasiel et al., 2016). Personal preference is a significant factor. Some students prefer learning face to face (Lawrie et al., 2014) and will feel disengaged in an online course. Disengagement is the primary reason for high dropout rates for Massive Online Courses (Rolfe, 2015). Other students favor remote learning (Hewitt & Stubbs, 2017) may not feel the need to come to the classroom (Lai & Savage, 2013).

6.5. Where do we go from here?

There are a variety of reasons why TiE fails. Technology cannot fix lousy teaching or low student engagement (Lai & Savage, 2013). Training and thought out curriculum are vital factors. The presence of information in technology alone does not facilitate the learning process (Lai & Savage, 2013). Students have to be engaged, and knowledgeable of the systems they use. Without proper implementation and planning TiE takes the form of passive consumption of knowledge (Henderson et al., 2015), losing any advantages it has over traditional teaching methods (Siraj, 2014).

7. The Ugly

So what is the verdict? On the one hand, technology is incredibly useful, and on the other, it has many flaws. We can start by looking at how research evaluates the impact of technology on education. As we discussed in “The Good” there are many tools used for many different educational purposes, therefore evaluating the relationship between technology and learning is a significant challenge. A starting point to a systematic evaluation of technology benefit to learning is its ability to redefine an educational task. The SAMR framework developed by Dr. Ruben Puentedura is a well thought out system that splits technology into four categories: Substitution: Technology acts as a direct substitute with no functional change; Augmentation: Technology acts as a direct substitute with functional improvement; Modification: Technology allows for significant task redesign; and, Redefinition: Technology allows for the creation of new tasks inconceivable.

In the context of this literature review, SAMR is used for two purposes: Evaluate the impact of using technology on the learning experience, and Digest methodology used to evaluate TiE.

7.1. Substitution

In itself, substitution does not necessarily render a tool ineffective. A scanned version of “War and Peace” while not offering many functional improvements over the actual book can be quite convenient for mobility. The burden of proof is on the researcher to justify why the technology they are studying is a useful tool.

An example of poor substitution is Liu and Liu (2013) experiment. The researchers assert that substituting pen and paper for 3D software improves the student’s ability to learn geometry. In this case, the researchers show little to no advantages to applying technology. The study concludes that it is the 3D aspect of the software helped the students understand the spatial dimension. Compared to pen and paper this is true, but the same “3D effect” can be achieved with simple physical objects. Plastic geometrical objects that could be taken apart, measured, and put back together would be a more cost-effective, interactive and hands-on experience that would

match or surpass the technological tool. There is no compelling proof that the substitution technology for traditional methods is necessary.

7.2. Augmentation

Augmentation is similar to substitution, but the technology offers a functional improvement. Referring to the previous example if “War and Peace” were converted into a digital epub format it could now be searched, bookmarked and highlighted there would be a functional improvement over the scanned version. In applying Augmentation to evaluating TiE the researcher has to be careful in setting up his variable, even if the technology seems inherently superior to a non-technological, in terms of the sheer number of functionalities the researcher still has to justify using the technology.

Ambrose and Palpanathan (2018) set up an experiment to demonstrate the technological advantage of Google Docs for learning English. Google Docs offers several features useful for this purpose including spell and grammar check, the ability of students and teachers to work in real-time on the same document, as well as saved revisions (that allow for comparison to pre-corrected versions). Unfortunately, the control variable is again pen and paper. The researchers could have employed several technological tools used for learning languages and or writing: M-learning technologies discussed by Siraj (2014), or the software utilized by Bodnar and Petrucelli (2016). This study fails to set up a proper control variable that would demonstrate whether this is the right tool for the job, or probe student preferences.

In order to gauge the effectiveness of a tool for learning the research has to compare apples to apples. Brasiel’s et al. (2016) research of mathematical tools in Utah classrooms, examines the effectiveness of fourteen different tools designed for the same purpose and applied in similar environments. The conclusions drawn from their research have a stronger foundation based on the methods.

7.3. Modification

The next step in evaluating the impact of technology on education allows for significant task redesign. Continuing from the previous

example, in addition to search and bookmarks the epub version of “War and Peace” can also be offered in audio format. The next paragraph examines an excellent case-study evaluating the effectiveness of a tool that fits into modification criteria.

Bluemel (2014) examined a tool called the “Parallel Corpus Teaching Tool” specifically designed for learning the Chinese language. The researcher did not compare the tool to other tools but explored the features of the software and demonstrated how each of them supported language acquisition. The researcher’s evaluation of the benefits of the functionality is detailed enough to show a precise and well thought out application of technology to learning. The tool not only defines a word but shows how to structure the word in a sentence, offer an English phonetic version and allows the user to hear the pronunciation. Doing the same tasks without this technology would be cumbersome and require numerous resources.

7.4. Redefinition

The last category of technology creates new tasks inconceivable without technology. Going back to “War and Peace”, the reader would be able to ask an artificial intelligence bot questions about the book. For example: “Who was Pierre Bezukhov’s mother?”

In section “Tolerance, Diversity and Growth” we discussed how Thompson’s et al. (2013) study employed multiple technologies to bridge the gap between two isolated communities in Korea and the USA. To achieve the same results without technology would have been inconceivable. In their own words: “This kind of interdisciplinary, cross-cultural exploration demonstrates the usefulness of technology to bridge content and worlds and the power of the arts to transcend language” (p. 9).

The SAMR framework is the foundation to build the structure that assesses the usefulness or the impact of a tool. The researcher has to understand the impact of the technology they are evaluating and approach the research in a meaningful way to address what and why makes technology useful.

In the literature, many studies asked meaningful questions that yielded significant

conclusions. However, several researchers employed poor techniques. Mtebe and Raisamo's (2014) research into the feasibility of adaptation of eLearning in higher education is one example. Students were asked to rate statements such as: "I would find mobile learning useful in my learning" and "People who influence my behavior will think that I should use mobile learning". Predictably, an overwhelming amount of students positively responded to the potential of learning through mobile technologies. A similar format of data collection conducted by Joan (2013) yielding no surprising results. Without knowing which technology or understanding how it affects learning, it is impossible to assess its value. Gauging public opinions on whether the person views TiE as "good or useful" offers limited insight into the phenomenon.

The same type of questions applied to a specific technology is also ineffective. Izadpanah and Alavi (2016) researched student perception of CALL (Computer Assisted Language Learning). Statements students were asked to rate were such as: "CALL makes lessons more interesting than traditional English instruction" and "CALL helps me develop my grammar" (p 149). The perception of a new tool may change as the user gets bored of it or gets to know similar tools that are better. Properly formulated questions are just as important as setting the valid control variable for the evaluation of the impact of technology.

7.5. The Dark Side of TiE

Several problems with the research and implementation of technology in education were identified. These are described as follows:

7.5.1. The Good and the Bad

Technology is not automatically better. The researcher has to examine the advantages and disadvantages of tools carefully. If the tool does not show significant benefits over non-technological teaching methods, is it worth using given those difficulties with implementation discussed earlier? The researcher needs to examine and justify why this tool is the best approach for this particular type of learning.

7.5.2. Control Variable and Questions

Studies that employ experimental format should carefully choose the control variable and questions for their experiment. In order to gauge the benefit of a given tool, it is much more useful to compare similar tools. If no tools are available, the author can choose to explore the unique benefits of that tool and how it aids the user.

7.5.3. User learning goals and personal preferences

In literature, several studies discussed the personal reasons why users fail to adapt to technology and but very few of them looked whether the technology is adaptive to the user (Sun & Wang, 2014). The question rarely asked is: Does this tool meet the user's learning goals and personal preferences? Though technologies like LMS that have been extensively studied and are well-funded (Kates et al., 2010), the research offers little understanding of the relationship between instructors, knowledge, and students (Lai & Savage, 2013). Additionally, little effort has been made in assessing the individual goals and needs of either students or instructors (Lai & Savage, 2013). The section titled "The Bad" demonstrated that the user disengages when they feel disconnected from the technology. Rolfe's, 2015 research of Massive Online Courses serves as an example of this phenomenon. Massive Online Courses are just too impersonal, resulting in a significant drop-out rate. When the user goals and needs are not assessed instead of the tool designed for the learner, the learner has to adapt to the tool (Henderson et al., 2015). The result is that the success of TiE is varied and inconsistent (Henderson et al., 2015).

The need to look into these questions is underpinned by excellent work such as Lai and Savage's (2013) probe into the relationship of the LMS and student-teacher interaction. Their research looks at technology and its effects on learning and teaching. The in-depth interviews with instructors and focus groups with students' research demonstrated that teachers and students feel that the LMS offers tremendous benefits for learning. The ability to access knowledge online through media such as e-text, video and audio files is acknowledged by the users to be among

the most useful features. Lai and Savage conclude that technology should offer flexible solutions to accommodate the teaching methods, level of technological adaptation, and personal preference. Their suggestion for further research to investigate knowledge acquisition outside the classroom shows a gap in the knowledge worth investigating.

Evmenova's (2018) study of supporting teachers by using Universal Design for Learning (UDL) further underpins the need for learning to be adaptive to the user through the implementation of technology. "UDL is a scientifically based framework for developing curricula that acknowledge learner diversity as a function of human variability" (p 147). UDL approaches learning through three principles: multiple means of engagement, multiple means of representation, and multiple means of action/expression. The researcher uses findings in neuroscience and research on cognitive learning to support the importance of technology in accommodating different learning styles through multiple means of engagement.

Although the goal of the study is to educate teachers, the research itself and the UDL methods employed underline the importance of learner diversity and using technology for diversification of content delivery. Evmenova emphasizes the use of different media (video, audio, e-text) as an effective tool for content delivery for successful learning. The researcher acknowledges the need to look deeper into patterns for using media to study. Her conclusion underpins the need for personalization of learning by stating that the optimal learning experience is a combination of technology meaningfully integrated into the curriculum and flexible, user-centered options for learning.

7.6. Adaptive Learning

Adaptive Learning movement has tried to address this problem by personalizing content delivery to users. Magdin and Turčáni (2015) utilized Educational Data Mining to automate the type of learning material shown to the user based on information stored about them in the LMS. Although this field is promising, developing the perfect algorithm is time consuming, costly and requires intensive research. The authors

themselves acknowledge that unique behavioural patterns and the time required for data analysis are limitations to developing a universal formula. Although adaptive learning through data mining is a viable solution, it is still in development.

8. Conclusion

Technology-based tools have been widely integrated into the learning process. Videos (Henderson et al., 2015), e-text (Sun & Flores, 2013), images (Kates et al., 2010), PowerPoint (Lumpkin et al., 2015) podcasts (Hewitt & Stubbs, 2017), and a plethora of other tools are used to teach a broad range of topics. From kindergarten to university, various e-learning tools are incorporated into teaching mathematics, sciences, languages, social sciences, computer learning, and a host of other subjects. Web-based Learning Management Systems like Blackboard facilitates communication between teachers and students as well as allow students to collaborate on projects. This phenomenon is worldwide with almost every single nation taking some technological initiative.

Time and resources have been invested in evaluating technologies in education, and survey perception of technology. Lack of agreed standards of measurement often leads to inflated positive ratings of TiE. This phenomenon resulted in a variety of technological implementation driven by clever marketing and hype rather than user needs and personal preferences. The present work identified several of the major problems with the way technology is perceived and evaluated. There is a gap in the research of the relationship between user goals, media use, and learning. Further research with improved methodologies into the phenomenon would offer a more meaningful understanding of how people use technology to learn.

9. Proposal for further research

This paper has identified a gap in the research into how individuals use technology to learn. The current trend in TiE is to evaluate how users use or feel about technology to learn. Very few of the studies focus on user needs and motivation as the foundation of technological development. With

the user needs as foundation technology has the potential to redefine learning by personalizing the process (Sun & Wang, 2014). The focus of the research must define the user needs, identify their learning goals and examine how to utilize technology to facilitate the acquisition of learning. Therefore, further research is needed related to examining learning through media outside of the classroom (video, audio, and e-text) and examining how the media is used to achieve the learning goals of adult users.

Why outside the classroom?

The teacher's ability and personality play can dramatically change the perception and use of technology. In order to eliminate this variable, research should be conducted on learning outside of the classroom, and solely on the relationship between the individual's learning goals in the process of learning and media usage.

What do you mean by adults?

Adults in this context refers to individuals enrolled in either secondary or higher education. The advantages of these two groups are that they are more likely to be very familiar with using media, and are more accessible as research subjects.

Why video, audio, and e-text?

Media is technology. Many of the studies discussed here use one or more media as building blocks in their platform for teaching and learning. Learning outcomes are influenced by the complex array of variables associated with various specific technology tools. In addition, other less well understood factors such as the level of user adaptation of the technology tools and incorrect or incomplete implementation may affect teacher effectiveness and student learning outcomes. Interestingly, media may either exacerbate or ameliorate these conditions.

In sum, there is clear evidence of successful learning through the implementation of technology including media. Using media may be seen as fun, it supports learner diversity, and there is clear evidence that it supports learning. However, there is a lack of a clear relationship between how people use it and how this use may vary depending on the individuality and learning goals of the user. This exploratory study has the potential to illuminate some of these dynamics with more rigorous methodologies and practical research questions.

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CRITICAL THINKING AND PHYSICS PROBLEMS

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KEY WORDS

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Comparison of students' CT
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ABSTRACT

Critical thinking is considered to be one of the most important abilities which help us to solve problems, interpret information or make decisions in everyday life. Every person needs to use critical thinking, therefore, it is important to develop students' critical thinking in all classes including Physics. We summarize various definitions of critical thinking and we describe the survey, where students solve problems whose solution requires critical thinking. We compare students' results to see if they can solve problems without physics content with better successfulness than the problems with physics content and to see how the school attendance impacts its development.

1. Definitions of critical thinking

To make decisions, choose criteria, solve problems, evaluate arguments or interpret limitless information, we use critical thinking skills. Every person needs to use critical thinking skills in certain situations. Experts say that critical thinking is not inherent (Gavora, 1995, p. 11). Therefore, it is important that students have an opportunity to learn how to think critically and how to improve this skill.

There are various definitions of critical thinking and experts understand this term in different ways. In 1989, the Iowa Department of Education published, "A Guide to Developing Higher Order Thinking Across the Curriculum", where they present an integrated thinking model (Iowa Department of Education, 1989, p. 7 – 9). They describe critical thinking as a part of complex thinking processes and they state:

Critical thinking behaviors involve reorganizing in meaningful ways the "accepted knowledge" from the content/basic thinking; (Iowa Department of Education, 1989, p. 7)

They divide critical thinking into three sub-categories, namely, analyzing, connecting, and evaluating. Next, they characterize these categories and list skills associated with each one (Iowa Department of Education, 1989, p. 18).

Subsequent to several years of research on the topic of critical thinking, the American Philosophical Association published, "The Delphi Report" which presents a consensus of views on the topic from experts from divergent fields such as philosophy, education, psychology (Facione, 1990). The report states in part:

We understand critical thinking to be purposeful, self-regulatory judgement which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgement is based. (Facione, 1990, p. 2)

The experts in the report also state that good critical thinking includes a skill dimension and also a dispositional dimension (Facione, 1990, p. 4). There are six cognitive skills identified in the report associated with critical thinking and these

include: interpretation, analysis, evaluation, inference, explanation, and self-regulation. These skills are then defined along with their respective sub-skills. The authors also state that these skills can be correlated with various cognitive dispositions to be exercised appropriately. These dispositions include: concern to become and remain generally well-informed, trust in the processes of reasoned inquiry, self-confidence in one's own ability to reason, open-mindedness regarding divergent world views, willingness to reconsider, and revise views where honest reflection suggests that change is warranted, etc. (Facione, 1990, p. 6–13).

The earliest research on critical thinking in Slovakia was conducted in 1994 by researchers from the faculty of education at Comenius University in Bratislava. As a result of their research, the authors describe critical thinking as a tool which helps the student to uncover connections, understand what he/she is learning and reach his/her own conclusions (Gavora, 1995, p. 7).

In contemporary society, critical thinking is considered to be one of the most important abilities. The Organisation for Economic Co-operation and Development (OECD) states:

Students will need to apply their knowledge in unknown and evolving circumstances. For this, they will need a broad range of skills, including cognitive and meta-cognitive skills (e.g. critical thinking, creative thinking, learning to learn and self-regulation); social and emotional skills (e.g. empathy, self-efficacy and collaboration); and practical and physical skills (e.g. using new information and communication technology devices). (OECD, 2018, p. 5)

Therefore, its development is essential for students' futures. Based on the State Educational Program in Slovakia, the development of critical thinking is included in the general educational aims for students enrolled both in primary schools (ŠPÚ, 2015a, p. 4) and secondary schools (ŠPÚ, 2015b, p. 4). These students should be provided with the opportunity to develop their critical thinking skills in all subjects, including physics.

While the development of critical thinking in all subjects is important (Kosturková, 2016, p. 37, Facione, 1990, p. 4), nevertheless, it can be hard for teachers to identify tasks and activities

to do so. One of the possible ways to develop critical thinking in physics classes is to have students identify physics mistakes in movies (Velmovská, 2011, 2014).

2. The survey focused on critical thinking and solution of physics problems

This quantitative survey was designed to evaluate how the physics content affects the successfulness of solution. Problems whose solution requires critical thinking were used. The following section describes the hypotheses, methodology, survey sample, and results.

2.1 Hypotheses

The survey employed the following four research hypotheses:

H1: Students of primary and secondary schools will be less successful in solving the problems with physics content whose solution requires critical thinking than in solving the problems without physics content whose solutions require critical thinking.

Based on the integrated thinking model mentioned above, critical thinking reorganizes the “accepted knowledge” from the content/basic thinking (Iowa Department of Education, 1989, p.7). When students solve problems they need to have some basic knowledge from the related area and only after that they can use critical thinking. Therefore, when students solve problems with physics content they need to have some basic knowledge from the related area of physics and then they can use critical thinking to reorganise this knowledge in meaningful ways. Students might miss basic knowledge from physics and therefore they may be less successful in solving problems with physics content than solving problems without it.

H2: Students who attended school for more years will be more successful in solving the problems whose solution requires critical thinking than the students who attended school for fewer years.

The length of school attendance might have a positive impact on the level of students’ critical thinking skills. Students who attended school for

more years may have more opportunities to develop their critical thinking skills and therefore, may be more successful in solving critical thinking problems than students who attended school for fewer years.

H3: Students from the class for intellectually gifted children will be more successful in solving the problems whose solution require critical thinking than the students of the same age from ordinary class.

Students from classes for intellectually gifted children may have better basic knowledge and therefore, may be more successful in solving critical thinking problems.

H4: Students from Slovakia will be as successful in solving problems whose solution requires critical thinking as students of the same age from a foreign country.

The aim of each educational system is to prepare students to be successful as contributing members of their respective society. Whereas critical thinking is one of the essential skills set in everyday life for students everywhere, it nevertheless, may be developed differently in schools contingent upon idiosyncratic societal differences. Despite of all these difference, each educational system tries to develop critical thinking in the best possible way. Therefore, students from disparate countries across the world, with their respective different education systems, may be equally successful in solving critical thinking problems.

2.2. Methodology

The data was collected utilizing a survey that incorporated ten problems whose correct solution requires students’ use of critical thinking skills. Five of the problems included physics content and five of the problems did not include physics content. The test was divided into two parts. The first part consisted of three problems with physics content and two problems without physics content. The second part consisted of two problems with physics content and three without it. The division of the test into two parts was purposely designed to avoid having students read four pages of text at one time.

The problems with physics content included the following five topics: density, temperature, heat conduction, the properties of liquids, and measurement of length. Based on the State Educational Program in Slovakia (ŠPÚ, 2015c), these topics are studied in the sixth grade and at the beginning of the seventh grade of primary school (the age range of these students is 11 to 12). The problems without physics content included the following five topics: starting a company, discovery of Angel's falls, an avalanche in the Cascade Range, flight hours of aircraft's captain, and ice hockey championship. A more complete description of the problems and solutions have been annotated elsewhere (Trúsiková, 2018). Statement 1 and 6, are examples of the problem without physics content and with physics content, respectively.

Statement 1: John has started a new company. Michael owns a company with a long tradition. New companies are more likely to fail than companies with a long tradition. Based on the previous information, we can say:

1. John's company will fail.
2. Michael's company will have a better profit than John's company.
3. Michael's company won't fail.
4. John's company is more likely to fail than Michael's company.
5. John's company is newer than Michael's.

Statement 6: In January 2017 was really cold in Slovakia. In mayor part of Slovakia, they measured the lowest average air temperature for the preceding thirty years. The air temperature decreased even under -30 °C in some places. Based on this information we can say:

1. January 2017 was colder than we expected.
2. The average air temperature in January 2017 was lower than in January 2016 in mayor part of Slovakia.
3. In January 2017 it snowed the most for preceding thirty years in mayor part of Slovakia.
4. The average air temperature was -30 °C in some places in January 2017.
5. The air temperature didn't decrease -30 °C in January 2016.

Each problem consists of a statement followed by five declarative sentences. Students

were instructed to circle the correct declarative sentences based on the information in each problem. They could circle multiple declarative sentences related to each problem. In response to problem one, the correct declarative sentences were items four and five. In response to problem six, the correct declarative sentence was item two. A five-point scale was used for the five declarative sentence options. A respondent received one point for each declarative sentence marked correctly. Therefore, each student could attain a maximum of five points for each problem. In total, students could reach 50 points; 25 points for solving problems with physics content and 25 points for solving problems without physics content.

2.3. Sample of survey

The survey was administered to three different schools in Slovakia (Grammar school in Nové Mesto nad Váhom, Primary school in Tvrdošovce and Primary school with the class for intellectually gifted children in Trenčín); and at one school in the USA (Eastern Hills High School in Fort Worth, Texas). Grammar school is a type of secondary school in Slovakia, where study the students who usually continue at some university.

The survey was administered to the Slovak students in February and March of the school year 2017/2018. The survey was administered to students from the USA in April of the school year 2018/2019. The age range of Slovak students was 12 to 18 and the age range of students from the USA was 16 to 18. Table 1 displays the number of students who completed both parts of the survey.

Table 1.
Number of participating students in the survey

	Slovak students	Students from the USA	In total
Number	160	39	199

2.4. Results

As noted previously, students could achieve a maximum of 50 points for successful completion of both parts of the survey. The highest score

was achieved by a second grade student of a grammar school in Slovakia. She achieved 47 points; 22 points for problems with physics content and 25 points for problems without physics content. None of the students participating in the survey reached 25 points for problems with physics content.

The four hypotheses were tested using the free software for statistical computing, namely, the R project (R Core Team, 2018). The first hypothesis tested was H1. The null hypothesis H01 was chosen for the purpose of data analysis. H01 is stated as follows:

H01: Students of primary and secondary schools will be as successful in solving the problems with physics content whose solution requires critical thinking as in solving the problems without physics content whose solutions require critical thinking.

In order to test hypothesis H01, two sets of data were compared; the number of points reached in problems with physics content and the number of points reached in problems without physics content. The results of students from the class for intellectually gifted children were not included in this analysis. Therefore, the results of the 185 students in the other three schools were compared. First, the Shapiro-Wilk (1965) test of normality was employed and revealed that there was not a normal distribution of data for either the set of data for the problems with physics content ($p_{stat} = 0.0353 < p_{crit} = 0.05$) or, in the set of data for problems without physics content ($p_{stat} = 0.002 < p_{crit} = 0.05$). Next, the Wilcoxon-Mann-Whitney nonparametric test (Fay, Proschan, 2010) was used to compare means of both sets of data and revealed that $p_{stat} = 0.02644 < p_{crit} = 0.05$. Based on an analysis of the means scores, the null hypothesis H01 was rejected. Then a comparison of the average number of points reached in problems with physics content (16.82 points) with the average number of points reached in problems without physics content (17.53 points) was conducted and revealed that students might have statistically better results solving the problems without physics content and therefore, hypothesis H1 is not rejected.

Next, hypothesis H2 was then tested. The null hypothesis H02 was chosen for the purpose of the analysis of the data. H02 is stated as follows:

H02: Students who attended school for more years will be as successful in solving the problems whose solution requires critical thinking as students who attended school for fewer years.

To test hypothesis H02 only the results of Slovak students were utilized. In addition, the results of students from the class for intellectually gifted children were excluded because only one class participated in the survey. The remaining six sets of data were then compared, corresponding to the seventh, eighth and ninth grade of primary school and the first, second and third grade of grammar school. In total, the results of 146 students were analyzed. These sets contained the total number of points reached in both parts of the test. The Shapiro-Wilk (1965) test of normality was used and revealed a normal distribution of the data for all grades. Next, a two-sample Student's t-test (Fay, Proschan, 2010) was used to calculate p-values in particular grades. A comparison was then made of the seventh-grade students' results with eighth, ninth, first, second, and third-grade students' results. Subsequently a comparison was then made of the eighth-grade students' results with ninth, first, second, and third-grade students' results. A comparison of the results continued in this way culminating in the comparison of the second-grade students' results with the third-grade students' results. P-values adapted by Benjamini-Yukutieli (Dohler, 2018) procedure are shown in Table 2 below.

Table 2.
P-values adapted by Benjamini-Yukutieli procedure

Grades	8 th	9 th	1 st	2 nd	3 rd
7 th	0.088	0.001	1.2 x 10⁻⁴	1.3 x 10⁻⁷	1.0 x 10⁻⁶
8 th		0.030	0.002	1.2 x 10⁻⁴	1.2 x 10⁻⁴
9 th			0.023	1.9 x 10⁻⁵	6.1 x 10⁻⁵
1 st				0.418	0.963
2 nd					0.202

P-values $p_{crit} < 0.05$ are marked in bold and the null hypothesis H02 is rejected in these cases. Comparing the seventh-grade students' results

with the eighth-grade students' results the null hypothesis H02 is not rejected, nor is it rejected comparing the first-grade students' results with the second and third-grade students' results, and the second-grade students' results with the third-grade students' results. The relatively small number of participating students is a limiting factor in making a wider generalization, but the results suggest that the length of school attendance might have a positive impact on the level of critical thinking.

Next, hypothesis H3 was tested. The null hypothesis H03 was chosen for the purpose of the analysis of the data. H03 is stated as follows:

H03: Students from the class for intellectually gifted children will be as successful in solving the problems whose solution require critical thinking as students of the same age from ordinary class.

In order to test hypothesis H03, two sets of data were compared. The total number of points reached by the eighth grade students (N = 28) from the primary school in Tvrdošovce (ordinary primary school) was compared to the total number of points reached by the eighth grade students (N = 14) from the primary school in Trenčín (class for intellectually gifted children). First, we used Shapiro-Wilk (1965) test of normality and determined that there was a normal distribution for both sets of data. With respect to the ordinary class of students the results were: $p_{stat} = 0.429 > p_{crit} = 0.05$, whereas the results for the class for intellectually gifted students, were $p_{stat} = 0.276 > p_{crit} = 0.05$. A Student's t-test (Fay, Proschan, 2010) was then employed to compare means scored and revealed that $p_{stat} = 1.74 \cdot 10^{-6} < p_{crit} = 0.05$. Therefore, the null hypothesis H03 was rejected. Comparison of the average number of points reached by students from an ordinary class (31.71 points) with the average number of points reached by students from class for intellectually gifted children (38.79 points), revealed that students from the class for intellectually gifted children might have statistically better results. Therefore, the hypothesis H3 is not rejected.

Finally, hypothesis H4 was tested. Six sets of data were analyzed including the results of the 16, 17 and 18 years old Slovak students (N = 72) and the corresponding results of 16, 17 and 18

years old students from the USA (N = 39). First, the Shapiro-Wilk (1965) test of normality was conducted to determine p-values. As indicated in Table 3, the p-values of particular sets of data are displayed. Based on the fact that in all sets of data, the $p > p_{crit} = 0.05$, the data distribution is considered to be normal.

Table 3.
P-values calculated by Shapiro-Wilk test

Age	P-values	
	Slovak students	Students from the USA
16	0.20	0.06
17	0.85	0.55
18	0.10	0.54

Next, a Student's t-test (Fay, Proschan, 2010) was conducted to compare the results of 16 years old Slovak students with the results of 16 years old students from the USA. The data analyses revealed that $p_{stat} = 0.002679 < p_{crit} = 0.05$, and the hypothesis related to the equality of means is therefore, rejected. The analyses then continued with a comparison of mean scores. Slovak students reached 37.0 points on average and students from the USA reached 29.55 points on average. Next, the results of 17 years old Slovak and USA students were compared in the same way, with the resultant p-values; $p_{stat} = 1.162 \cdot 10^{-8} < p_{crit} = 0.05$. Based on these results the hypothesis about the equality of means is rejected. Slovak students reached 38.52 points on average and students from the USA reached 31.53 points on average. Finally, the results of 18 years old Slovak and USA students were analyzed and revealed that $p_{stat} = 4.468 \cdot 10^{-7} < p_{crit} = 0.05$. Therefore, the hypothesis related to the equality of means is rejected. Slovak students achieved 38.63 points on average whereas, students from the USA achieved 27.82 points on average. The data suggest that Slovak students might reach statistically better results than students from the USA in all age categories.

2.4. Discussion and Conclusion

There were four hypotheses tested in this survey and following provides a brief summary and commentary. Hypothesis H1 is not rejected

because the data indicates that students might reach statistically better results in solving survey problems without physics content. Students may likely have already studied the terms used in the problems with physics content. However, at the same time, students might not understand all of these terms and concepts correctly and therefore, may be missing the key knowledge that could be reorganized by critical thinking.

Hypothesis H2 is not rejected because the comparison of students' results suggests that the length of school attendance might have a positive impact on the level of critical thinking. However, there was a very small number of students who participated in the survey. Therefore, inferring broader generalizations in this regard cannot be made. Subsequent research with a larger number of subjects is warranted to test this hypothesis.

Hypothesis H3 is not rejected because the data indicates that students from the class for intellectually gifted children might reach statistically better results than students of the same grade from an ordinary class. It may be that students from the class for intellectually gifted children might have better level of basic knowledge. It may also be true that their critical thinking is better developed. Therefore, they may have more basic knowledge to be reorganized and they also can reorganize in a better way than the students from the ordinary class. These speculations need investigation with a larger student sample with instrumentation designed to address these differences.

Finally, hypothesis H4 is rejected. The data indicate that Slovak students might reach statistically better results than students from the USA. However, only a small number of students with the age range 16 to 18 participated in the survey (39 students from the USA and 72 students from Slovakia). Therefore, the very small sample size precludes broader generalizations. Another limiting factor to wider generalization is difference in the types of schools included in the study. For example, the Slovak students all attended grammar schools. A very high percentage of students who attend grammar schools in the Slovak Republic go on to attend the university. On the other hand, students from the USA who participated in the survey, were all enrolled at a regular high school. Subsequent studies might test these hypotheses with larger numbers of students controlling for the type of secondary school in both countries.

All data is considered as a starting point for the next research. It can be used to design more problems whose solution requires critical thinking. Mentioned problems should include different physics topics. The data will be also used to design the indicators to assess the level of critical thinking in the education of physics.

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